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Knowledge-Based Economy (KBE): An investigation of theoretical frameworks and measurement techniques in the South East Asian region

A dissertation submitted by
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Abstract

Recent times have seen knowledge take on increasing importance as one of the most important drivers of economic growth. The difference between a knowledge-based economy (KBE) and a resource-based one is that with the former, the main feature is the ability of individuals and firms to generate innovation. Other forms of competition, such as through pricing strategies and access to resources, become secondary. Generally speaking, knowledge is information combined with technology that dramatically increases output. Organisations such as the Organization for Economic Cooperation and Development (OECD), Asia Pacific Economic Cooperation (APEC), Australian Bureau of Statistics (ABS) and the World Bank Institute (WBI) have developed different KBE frameworks through which to indicate the extent of individual countries' knowledge base and to implicitly guide policy. However, these frameworks have little in the way of theoretical underpinnings, and applying them universally across all countries in different regions, at different stages of development and with different institutional, social and economic characteristics may be misleading and result in inappropriate policy responses. This thesis proposes a framework which clearly distinguishes input-output indicators of a knowledge-based economy under four important dimensions: acquisition, production, distribution and utilisation. Indeed, this study attempts to adapt measure and investigate them using a practical policy oriented approach for selected Association of South East Asian (ASEAN) and emerging economies which are endeavouring to transform from a resource-based to a knowledge-based economy. The results of this study indicate that theoretically the knowledge-based economy concept is not a new concept and has in fact been present in the literature since the industrial revolution. However, the extent of KBE in cross-country studies, measurement techniques and innovation system studies is very recent. This research demonstrates the concept of the national and regional innovation system, and how to apply recent non-parametric techniques like order-m, order-alpha to rank the best practice countries in this field. Most of the cases, including Singapore, South Korea and Philippines come as frontier countries in both scale and pure technical efficiency of non-parametric analysis. We believe an important contribution can be made to the literature, whether it is the application of Data Envelopment Analysis, Malmquist productivity analysis, the introduction of most productive scale size and peer countries, order-m, order-alpha, TOBIT model and finally the bootstrapping technique in this KBE innovation study.

CERTIFICATION OF DISSERTATION

The work submitted in this dissertation is original, except as acknowledged in the text. The material herein has not been submitted, either in whole or in part, for any other award at this or any other university except where acknowledged.

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Munshi Naser Ibne Afzal (candidate) Date

ENDORSEMENT

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Professor Roger Lawrey (supervisor) Date

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Professor Jeffrey Gow (associate supervisor) Date

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Research Outputs from this thesis

Afzal, M. N. I. (2014). An empirical investigation of National Innovation System (NIS) using Data Envelopment Analysis (DEA) and the TOBIT model. *International Review of Applied Economics (IRAE)*, *28*(4) (**accepted & forthcoming**). [Taylor & Francis publication house, Scopus, SSRN, ISI, ERA and Australian Business Deans Council (ABDC) indexed]

Afzal, M. N. I., & Lawrey, R. (2014). Measuring the importance and efficiency of research and development (R&D) expenditures in the transformation of Knowledge-Based Economies (KBEs): A case study of the ASEAN Region. *International Journal of Asia Pacific Studies*, *10*(1), 33-47. [ERA, Scopus, ABDC indexed]

Afzal, M. N. I. (2013). Are science valleys and clusters panacea for a knowledge economy? An investigation on Regional Innovation System (RIS): concepts, theory and empirical analysis. *Asian Research Policy (ARP)*, *4*(2), 114-125. [**ARP Best paper award 2013**][SSRN indexed]

Afzal, M. N. I., & Lawrey, R. (2013). National Innovation System (NIS): An empirical investigation with robust non-parametric partial frontier analysis. *Margin- The Journal of Applied Economic Research.* (under revision).[SAGE publication, ERA, Scopus, ABDC indexed]

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Afzal, M. N. I., & Lawrey, R. (2012a). KBE frameworks and their applicability to a resource-based country: The case of Brunei Darussalam. *Asian Social Science*, *8*(7), 208-218.[ERA, ABDC indexed]

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Afzal, M. N. I., & Lawrey, R. (2012c). A measurement framework for Knowledge-Based Economy (KBE) efficiency in ASEAN: A Data Envelopment (DEA) window approach. *International Journal of Business and Management*, *7*(18), 58-68. [ERA, ABDC indexed]

Afzal, M. N. I., & Lawrey, R. (2012d). Evaluating the comparative performance of technical and scale efficiencies in Knowledge-Based Economies (KBEs) in ASEAN: A Data Envelopment Analysis (DEA) application. *European Journal of Economics, Finance and Administrative Sciences*, *51*(8), 81-93. [Scopus, ERA indexed]

Afzal, M. N. I., & Lawrey, R. (2012e). Investigating World Bank Knowledge Assessment Methodology (KAM) using Data Envelopment Analysis (DEA): A study in ASEAN region. *Research Journal of Science and IT Management*, *1*(12), 32-38. [ISI indexed]

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Acronyms

ABS	Australian Bureau of Statistics
APEC	Asia Pacific Economic Cooperation
ASEAN	Association of South East Asian Nations
BCC	Banker, Charnes and Cooper model
CCR	Charnes, Cooper and Rhodes original model
COMPUSE	Computer users per 1000 population
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DRS	Decreasing Returns to Scale
DMU	Decision Making Unit
EDUEXP	Education expenditure
EMS	Efficiency Measurement System
FDI	Foreign Direct Investment
GZGDP	Growth of real GDP
HITECHEXPO	High-tech export
IPR	Intellectual property rights
IRS	Increasing Returns to Scale
KAM	Knowledge Assessment Methodology
KBE	Knowledge Based Economy
KNOWTRANS	Knowledge Transfer rate from university to industry
LRQUA	Legal and regulatory quality
MPI	Malmquist Productivity Index

MPSS	Most Productive Scale Size
OECD	Organisation for Economic Co-operation and Development
PTE	Pure Technical Efficiencies
RDEXP	Research and development expenditure
SE	Scale Efficiencies
SECONDEN	Secondary enrolment
STAR	Number of Scientific and Technical Journal articles per year
TFP	Total Factor Productivity
TRANS	Transparency of government policy is satisfactory
TSE	Technical and Scale Efficiencies
VRS	Variable Returns to Scale
WBI	World Bank Indicator
WCY	World Competitiveness Yearbook

CHAPTER 1 INTRODUCTION

1.0 Introduction and synopsis of this research

This study commences by investigating the existing Knowledge Based Economic frameworks (KBE frameworks) developed by the World Bank, OECD, APEC and ABS. This research found that existing KBE frameworks have proposed 128 or more knowledge indicators or variables for 150 countries. It also highlighted certain pillars of the knowledge economy where they divide the variables under each of those pillars and rank countries according to the observations on each variable. For instance, R&D expenditure as a percentage of GDP ranks Sweden, Japan, and South Korea as the top three countries. However, some anomalies or shortcomings in existing frameworks have been observed whereby it was quite difficult to judge the universal applicability of those frameworks to measure a country's knowledge economy performance. That is the motivation to build a generalisable measurement framework to investigate efficiency, productivity and the long term sustainability of KBE policies in selected South East Asian countries (mostly Association of South East Asian in short ASEAN) and emerging knowledge economics.

Moreover, in the current KBE frameworks, there are no agreed quantitative measurement techniques to benchmark the knowledge acquisition, production, distribution or dissemination and utilisation dimensions. Data Envelopment Analysis (DEA) - a non-parametric technique - is used to investigate input-output indicators from the KBE frameworks based on data availability and Australian Bureau of Statistics (ABS) assumptions. The conceptual framework, definition of knowledge economy, theory, KBE input-output indicators, technical, scale, pure efficiency and productivity measurement make up the first four chapters of the analysis. In chapter five, the World Bank Knowledge Assessment Methodology (KAM) and how the methodology could be improved using non-parametric techniques such as DEA, FDH etc is investigated.

In the remaining chapters this study investigates national and regional innovation systems, its policy issues, and the use of quantitative methodologies including the latest non-parametric techniques, for instance, order-m and order-alpha. In short, this research is based on an investigation of knowledge-based economy frameworks, innovation policies, as well as the application of quantitative methodologies to rank and measure efficiency, productivity of selected ASEAN and certain emerging knowledge economies. This is done in order to widen the knowledge-based economy concept beyond the current frameworks and to investigate the pros and cons of the existing frameworks in detail.

1.1 Background

Knowledge economy and knowledge-based economy (KBE) are often used synonymously. 'Knowledge economy' is the older of the two concepts, with its origins in the 1950s when Machlup started his research on the knowledge economy framework in the United States (Cooke & Leydesdorff, 2006; Leydesdorff, 2006). However, the importance of knowledge as a driver of economic growth was recognised long before this. Although it was not explicitly termed knowledge economy at the time, many economists began to realise the importance of knowledge in the late 19th century. Alfred Marshall suggested that "knowledge is our most powerful engine of production" and that organisation facilitates the growth of knowledge (Marshall, 1890, p.115). The OECD currently defines KBEs as "economies which are directly based on the production, distribution and use of knowledge and information" (OECD, 1996, p.11). This approach to defining KBE is reflected in the World Bank and APEC approaches. Whilst the scope of KBE is vast, the analytical tools, precise theoretical background and development process of indicators for the mapping and measuring of KBE performance are loose at best (Krisciunas & Daugeliene, 2006).

The impact of knowledge as a driver of economic growth was recognised and developed by the Austrian school in analysis of growth and entrepreneurship in the early 20th century. Schumpeter considered the "new combination of knowledge" as an important element for innovation and entrepreneurship (in Cader, 2008). The Schumpeterian concept of "creative destruction" postulates that economic growth occurs via knowledge creation and innovative companies grow while firms which fail to innovate are destroyed (Schumpeter, 1942). Another Austrian, Machlup (1962), was concerned with the intensity of the highly-skilled labour force and measured the knowledge intensity of different sectors of the U.S. economy (Cader, 2008). Machlup (1962), who first built a formal KBE framework, considered six subsectors in the production sector of the economy: i) education, ii) research and development (R&D), iii) artistic creation, iv) information technology, v) information services and vi) communication media. In general, Machlup (1962) highlighted the significance of knowledge production for economic growth through competition, sharing and diffusion in modern economics, and stimulated subsequent research into the knowledge economy framework.

For instance, in 1974, Hayek in his Nobel Prize lecture (The Pretence of Knowledge) said "people learn by doing and acquire new knowledge through the competitive market process. Therefore, the competitive market process, from the Austrian perspective, has led to beneficial interaction among market participants. This process, over time, reduces ignorance to manageable levels for economic agents, promotes the discovery of knowledge that was not previously available and could contribute to economic growth" (in Lin, 2006, p.326). The emphasis on free markets is very important for the Austrian School and stood in stark contrast with the Keynesian approach which were here to dominant. The basic premise of Hayek and others of the Austrian School is that the economy is too complex to model but can be explained through systematic verbal argument, whilst the free market economy will automatically move to a more knowledge-based economy. Research continued on the knowledge economy, with new growth theory economists, led by Romer (1986), Lucas (1988) and others (Lin, 2006) attempting to measure knowledge in KBEs. The core argument put forth by KBE researchers is that investing in knowledge can increase the productive capacity of the other factors of production whilst also transforming them into new products and processes. The other key feature of the theory is that knowledge leads to increasing returns to scale in production. Conventional production functions assume diminishing returns to scale, where marginal costs increase. However, with knowledge-intensive products, the fixed costs of production are large, but the variable costs of production are small (Lee, 2001). Since then, KBE research has developed to today's modern KBE frameworks (Cader, 2008). KBE research transcends disciplinary boundaries whilst studies from a sociological and cultural perspective also make valuable contributions to the study of transition. For example, Evers (2003) studied the social and cultural preconditions as well as consequences of reaching the stage of a knowledge society for Malaysia and Indonesia.

This research investigates the appropriateness of using mainstream KBE frameworks as developed by the OECD, WBI, ABS and APEC. In this study there is no formal literature review chapter, with the literature instead discussed in each chapter where applicable.

1.2 Statement of the problem and rationale

This study attempted to focus on how researchers can quantify knowledge-based economic growth, in order to examine efficient and sustainable innovation policy for rapidly developing countries like South Korea, Singapore and other emerging knowledge economies in the South East Asian region. There are several existing KBE frameworks proposed by the World Bank, OECD, APEC and ABS. These frameworks attempt to articulate the measurement variables and techniques to quantify the extent of knowledge-based development in the countries they study. However, there are short comings of the existing frameworks; for instance, the frameworks do not focus extensively on the national and regional innovation system which it is believed to be a very important integral part of the overall knowledge-based economy. This study also focusses on some key future challenges for the regional/national innovation system of these best practice countries.

The existing frameworks (OECD, APEC, ABS and WBI) do not have sufficient focus to measure KBE in the South East Asian region (ADB, 2013). This study marks out ground breaking work in terms of moving beyond the current statistical constraints to develop a robust KBE measurement technique to be applied to selected South East Asian countries**.** The investigation of knowledge economy indicators takes into account whether the environment is conducive for knowledge to be used effectively for economic development.

Thus far, different frameworks (OECD, APEC, ABS and WBI) have been developed, although not all are being used adequately to develop KBE indicators. Moreover, the issue of acquiring, producing, distributing and utilising knowledge and managing it in a meaningful way are two different things. Some countries do not have a problem with acquiring knowledge but have a problem when trying to utilise it in production processes. The issues and research questions presented here include:

1. To examine whether existing frameworks can explain KBE?
2. Is there any need to include or omit new variables in the existing frameworks , or
3. Is there a need for a new conceptual framework of KBE to compare the issue of measurement technique of different KBE indicators for selected South East Asian countries?

How to develop efficient national and regional innovation systems in the knowledge economy are key challenges for every country. This research also aims to answer the following research questions:

4. What are the potential input factors of the national and regional innovation system (in the case of ASEAN and emerging countries)?
5. What are the potential output factors of the national and regional innovation system?
6. How can the efficiency of the national and regional innovation system be evaluated?
7. What innovation policies lead to best performance in countries?

Findings from this research will provide answers to these questions and will be able to provide some suggestions and guidelines for policy makers of these countries.

1.3 Methodological approaches

The thesis consists of six analytical chapters using the qualitative methods of descriptive statistics, econometric tools and non-parametric analysis. Chapter 1 and 2 investigate the historical background of KBE theories, selected South East Asian countries' economies and the explanation of neo classical vs. new growth theory. Chapter 3 uses econometric techniques and involves the use of beta coefficient techniques to investigate important KBE input-output indicators and productivity analysis for ASEAN-5 countries. Chapter 4 examines the technical and scale efficiency of KBE input-output indicators using Data Envelopment cross-section analysis. The study takes two base years, for instance 1995 and 2010, to investigate the differences in scale efficiency of selected South East Asian countries' KBE input-output variables. Chapter 4 also highlights DEA Window analysis which essentially refers to the time series analysis of KBE variables from 1995 to 2010.

Chapter 5 consists of two case studies where DEA scale size, efficiency scores and most productive scale size concepts are used. One case study discusses the best way in which to achieve R&D efficiency and mathematically shows the most productive scale peers for inefficient countries, while the other case study critically investigates the World Bank Knowledge Assessment methodology (KAM) using non-parametric techniques focussing on DEA. In the second case study, it is argued that the DEA technique explains the countries' position in KBE more robustly than the existing normalisation technique used by the World Bank.

Finally, in Chapters 6 and 7 this study investigates the national and regional innovation systems of selected knowledge economies including South East Asian countries. It is argued that national and regional innovation systems are an integral part of the overall knowledge-based economy which is missing in existing KBE frameworks (for instance World Bank, OECD, ABS and APEC frameworks). This study applies the latest non-parametric technique, for instance *order-alpha*, in Chapter 6 and *order-m* in Chapter 7 to benchmark the efficient countries and explain why their efficiency score vary among the different knowledge economies. In order to investigate and explain the determinants of efficiency in the national innovation system model, the present study uses the TOBIT regression model. This study applies the TOBIT model for censored regression analysis based on DEA efficiency scores in Chapter 6. It is argued that how innovation leaders achieve best practice innovation policy while transferring their economy from resources-based to knowledge-based.

Each analytical chapter provides details on the methods used, sources of data and estimated models. Non-parametric efficiency software used including EMS, DEAP 2.0, FEAR, STATA and E-views 7 for the cross-section and time series analysis.

1.4 The case of ASEAN

Southeast Asia especially the five founder ASEAN countries, have been the world's leading emerging economies for several years. In order to promote economic, cultural and political cooperation in the region, the Association of Southeast Asian Nations (ASEAN) comprising Indonesia, Malaysia, the Philippines, Singapore and Thailand, was established in 1967. Brunei, Myanmar, Laos and Vietnam joined later. The ASEAN economies, particularly the ASEAN-5 (Indonesia, Malaysia, the Philippines, Singapore and Thailand) have been pursuing export-led and foreign direct investment-led development strategies. In earlier decades, the economic development of the ASEAN-4 (excluding Singapore) was largely resources-based and they competed in the world market as exporters of primary products, both agricultural and mineral. In the late 1980s, the ASEAN-5 began to move from resources-based to industrialised economies and steadily graduated to the World Bank's middle income and high-income economies as a result (Yue, 1999).

Growth in the ASEAN-5 has been accompanied by rapidly falling unemployment rates and poverty incidence. However, in the light of the regional currency and financial crisis of 1996-1997; Thailand's annual export growth fell from 24% in 1995 to -1.9% in 1996 and 3.2% in 1997; Malaysia's fell from 26.6% in 1995 to 7.3% in 1996 and 6.0% in 1997; Indonesia's plumetted from 18.0% in 1995 to 5.8% in 1996, recovering to 11.2% in 1997 (Lo, 2003). After the slowdown of economic growth during these years, the aforementioned countries began to question the sustainability of their development policies. KBE can be considered as an alternative or complementary development policy option for long run, sustainable growth. In order to transform into KBE, countries should know the key KBE dimensions in which to invest.

1.5 Organisation of the thesis

This thesis follows a research paper arrangement consisting of six analytical chapters. The author of this thesis made the major contribution in all the published articles that form the basis for each chapter. The chapters are linked to each other under the broad category of knowledge–based economy frameworks, concepts and innovation policies, although they are separable in the context of identifying literature and addressing specific issues and research questions. Following the introduction, Chapter 2 investigates the formal definition of knowledge economy whilst also providing a historical background and overview of selected South East

Asian countries. Chapter 2 also investigates a case study on a resources-based economy, namely Brunei Darussalam. Chapter 3 proposes a policy-focussed KBE framework based on the OECD 1996 KBE definition and investigates the most important input-output KBE variables for selected South East Asian countries. Furthermore, Chapter 4 also examines the enabling condition of knowledge-based economies in selected ASEAN countries using the latest non-parametric (malmquist productivity analysis) technique to show the neoclassical vs. knowledge-based productivity growth in ASEAN-5 countries over a 16 year time frame. Chapter 4 applies the policy-focussed KBE framework using the DEA method for time series and cross-section analysis; Chapter 5 discusses two case studies relevant to the R&D efficiency and World Bank KAM application.

Chapters 6 and 7 investigates national and regional innovation systems-concepts, theory and empirical analysis using the latest techniques of *order-alpha* and *order-m* to benchmark the best practice countries among emerging knowledge economies. These two chapters discuss innovation policies, knowledge cluster approaches, and the importance of science valleys and techno parks etc. in a knowledge-based economy. A national and regional innovation system has recently come into consideration as part of best-practice for overall knowledge-based development, although this has not yet been addressed by any existing KBE frameworks. With this in mind, the present study rigorously investigates these two issues. Finally, Chapter 8 includes overall policy discussion of our selected South East Asian countries and emerging countries in their attempts to develop a knowledge-based economy whilst also demonstrating possible future challenges in this regard.

CHAPTER 2: EVOLUTION OF KBE THEORIES

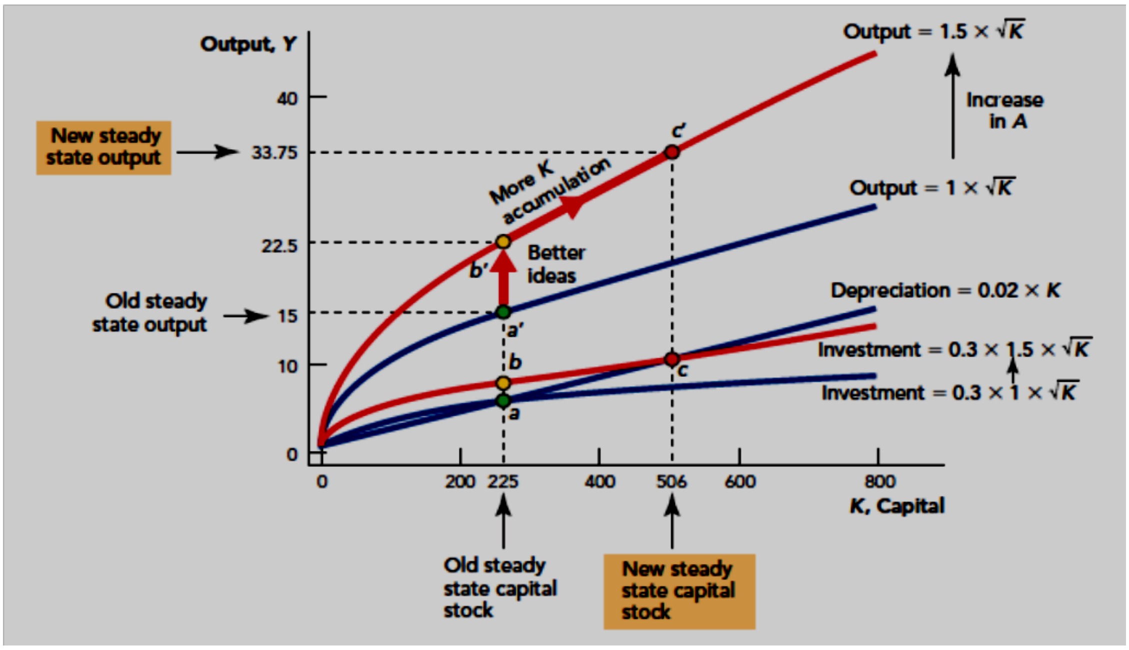
2.0 Historical background of knowledge economy theories

There are two fundamental types of economic growth, namely catching up and cutting edge growth (Cowen & Tabarrok, 2009). It is important to visit these two concepts in the introduction chapter in order to understand the policy implications of selected ASEAN and emerging countries in their transition towards a cutting edge or knowledge-based economy. This research begins with the concept of catching up growth process; a process which presents countries with a fantastic opportunity to accumulate wealth and become rich. With the catching up process, poor countries need not invent or invest in new ideas, and must only adopt technology which has already been pioneered by developed countries. For instance, catching up countries like China grow primarily through capital accumulation and adopt simple ideas or technology from the developed world which in turn massively improves the productivity of Chinese factors of production. This was the early growth strategy of selected South East Asian countries including South Korea, Singapore, Indonesia, Malaysia, Thailand and the Philippines.

However, in order to understand the cutting edge growth process, we can take the example of a resource poor country such as Japan. Japan is one of the world's leading economies and a shining example of the cutting edge growth model. Economic growth in the cutting edge model primarily depends on new innovation and knowledge. However, developing new knowledge is more difficult than adopting already existing ideas. For instance, it is easy to understand the technique of calculus at a certain time period but it takes a genius to invent it. Therefore, countries on the cutting edge develop primarily through ideas or new knowledge generation.

In order to understand the cutting edge growth process, we must start from neo classical Solow growth model. Robert Solow (1957, 1960) pioneered to explain the formally neo classical growth process through mathematical modelling. The Solow model predicts zero economic growth or steady state condition in the long run. He argued that in the long run, the capital stock stops growing because *Investment = Depreciation* and if the capital stock is not growing then further output of the economy also stops. Hence, the economy reaches a steady state condition. However, most of the developed countries have been growing for over many years up until the present day. This is because of innovation and technological improvement which sailed the growth process of these developed countries in the long run (Romer, 1986, 1990). Hence, we can say that better ideas/knowledge/innovation can keep the economy growing even in the long run. Now, if we can put this concept into the conventional Solow model, how does it look?

Figure 2.1: Better Ideas/New knowledge Generate More Output and More Capital Accumulation



According to Cowen & Tabarrok (2009), Figure 2.1 shows the process of how new ideas can break the steady state stage and propel long run growth. Solow considered the assumption of perfect competition at the beginning, whereby he argued that capital and labour would be paid their marginal products, and if either changed on its own, there would be diminishing returns. Whatever fraction of the growth of actual output could not be attributed to either labour or capital input, was termed as a technical change parameter in the model as A of (t). Solow's growth model looked like $Y=A(t)F(K,L)$ and the equation meant that the growth of output/income was a function of the accumulation of labour and capital multiplied by an arbitrary constant which represents the rate of growth of knowledge. Here, *A denotes (Solow residuals)* which also means new ideas and a higher *A* means that we are working with new ideas which can increase output from the same level of capital. Thus, we begin with *A* = ideas = 1. The economy is in a steady state and output = 15 (at point *a*'). Now, we assume that *A* increases to *A* = 1.5. Hence, new ideas produce more output from the same capital stock, from 15 at point *a*' to 22.5 at point *b*'. However, with greater output, investment also increases and moves from point a to point *b*. Since investment is now greater than depreciation, capital begins to accumulate. Therefore, capital accumulates and the economy grows until investment is once again equal to depreciation at point *c* with output now measuring 33.75 (at point *c*'). New ideas or innovation in new knowledge-based economies directly increase output and by so doing also indirectly increase capital accumulation. Hence, before we reach the new level of output, ideas may have improved even more and the economic growth process continues in the long run (Cowen & Tabarrok, 2009).

The first part of this diagram shows how catching up countries grow through capital accumulation and that once they reach the steady state stage, they need to focus on the cutting edge growth model which is based on new knowledge and innovation. This is the core concept of a knowledge-based economy. The knowledge based economy is essentially the second stage of the growth process when a country wants to transit from catching up to cutting edge. Different schools of thought have articulated this concept in their analysis. This study, and particularly the present chapter, tries to sum up the different views of knowledge-based economy theories in. Over the last two decades, concepts like the knowledge-based economy (KBE), national/regional innovation systems, information economy, digital economy or new economy have appeared and have significantly influenced science and technology policies. Whilst the OECD (1996), World Bank (2002) and APEC (2000) have identified the existence of the knowledge-based economy, the question remains as to what extent these concepts have any solid theoretical base (Afzal & Lawrey, 2012a, 2012b, 2012c. 2012d; Godin, 2006).

An economy of ideas or innovation was in existence long before the first industrial revolution and had been contributing to the intellectual, spiritual and economic wealth of communities since the dawn of civilisation. However, a great deal of knowledge was poorly distributed and inaccessible to the vast majority of people (Rooney et al., 2003; Dolfsma, 2001; Lundvall, 1992; Nelson, 1993; Godin, 2006; Boettke, 2002; OECD, 1996; WBI, 2002; APEC, 2000). Suitable and adequate institutions to advance and diffuse knowledge were not sufficiently developed to facilitate large scale networking of knowledge. Indeed, these days the picture is very different with the national or regional innovation system (Lundvall, 1992; Nelson, 1993). Hence, knowledge as something which exists within and between people (tacit and codified) and which is dependent on meaning through interpretation by individuals and groups differs distinctively from than what we call data and information.

Adam Smith (1776) first emphasised the importance of knowledge or new ideas by giving a simple example of a pin factory. He introduced a remarkable concept, 'Division of labor' where he postulated that a large number of pins can be produced through specialisation in the course of division of labour. He argued that through division of labour one can achieve specialization in the production process and thus produce more in contrast with non-division of labour or conventional processes. Specialisation improved the productivity of production factors, and particularly labour. His famous book, An inquiry into the nature and causes of wealth of nations, was the starting point in our understanding of the concept of productivity, which is a key component of the knowledge-based economy.

Economists previously thought that before all the factors of production, physical capital or even human capital tends to show diminishing returns. The diminishing return concept was first formally introduced by David Ricardo (1772-1823) who demonstrated this concept through a famous corn model. He said the idea of diminishing return was that after a certain point, each successive effort might produce less output. The first barrel of fertilizer does a lot, but the tenth only burns the crops (Warsh, 2007). However, one important component of the knowledge-based economy, besides productivity, is the increasing return in contrast with diminishing return. Increasing return usually occurs through productivity. If we take the example of Smith's pin factory, the greater the specialisation, the more efficient the production process, and thus the lower the price. The lower the price/cost, the more pins one can sell, and the more one sell, the higher the profits. Hence, a greater return for the same effort, which results in increasing returns to scale. Production factors along with new ideas and technology can usually offset the diminishing returns of factors of production. This is one of the important features of the knowledge-based economy.

Another economist, Alfred Marshall (1890), helped us to understand the importance of knowledge in economic growth. He introduced two ground breaking concepts in economic literature, namely scale economics and size of the market. Marshall argued that internal and external economics of scale can generate an enormous amount of production which can raise the wealth and prosperity of a nation. He said that the more extensive the virtual spill over or externalities, the more external economies freely available to all and the larger the size of the market, thus resulting in an enonomy's higher growth process. His concept was later termed economics of scale (Foray, 2004). Modern knowledge economies have witnessed this concept by seeing the success of Silicon Valley, Route-128 or South Korean cheaboll cluster; all of which used economies of scale to form a large high-tech cluster and overcome market size through the introduction of ICT.

Recently economists have attempted to articulate the theories of knowledge-based economy and innovation policies under two schools of thought, namely new growth theories and evolutionary economic theories. Evolutionary economic theories (also referred to as system theories) fundamentally explain the national and regional innovation system of a country. The underlying assertions of evolutionary economic theories are the perception that innovation and the technological and organisational changes are key drivers of long-run economic growth (ABS, 2002). Rather than viewing the market as in a static condition, this school specifically acknowledges that the market is constantly changing and firms must innovate in order to adapt to the changing environment. The core idea of evolutionary or national/regional innovation system theories is that knowledge flows within the whole system by interacting with different micro and macroeconomic agents such as research institutes, governments, universities, venture capitalists etc. The innovation does not follow a linear model, but rather continues in a non-linear direction from the non-commercial sector (such as research institutes, universities) to the commercial sector. The concept of evolutionary economics is new and was fully recognised by the Austrian school in the early 20th century (Metcalfe, 1995). The Austrian school stated that knowledge plays the central role in evolutionary economic models which are a crucial part of a competitive market environment. Austrian economist Joseph A. Schumpeter (1883-1950) was the prominent contributor to evolutionary economics (ABS, 2002). It was in fact him who came across the idea of innovation based competition in modern KBE. The new growth theory, technological change, endogenous growth, and long run sustainable development by increasing returns of capital are the offspring of Schumpeter's theory of economic development through creative destruction.

To understand the concept of creative destruction, Aghion & Howitt (1992, p.324) cite Schumpeter's (1942) words in their paper on Econometrica, "The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumer's goods, the new methods of production and transportation, the new markets...[This process] relentlessly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of creative destruction is the essential fact about capitalism". This concept is thought of as the origin of endogenous growth theory at the later stage.

The concept of knowledge-based economy derives from another famous theory known as the endogenous growth model developed by Paul Romer (1990) and improved by Helpman & Grossman (1991), and Aghion & Howitt (1992). They showed that technological advancement can be the most important determinant for sustainable economic growth. All of them are considered as modern growth economists, and argued that there are increasing returns to scale to capital investment (rather than constant returns) because of the externality created by stock of knowledge. All of these models and schools are considered as the theory of knowledge in the economics literature.

Charles Jones (1998) observed the differing growth concepts from Adam Smith to Paul Romer and made a conclusion in his book '*An Introduction to Economic Growth'*. He asserted that Adam Smith's division of labour focussed on specialisation and market size as the preconditions for growth. Later, Mills, Marshall, Marx and Solow raised the fundamental question; Why are we so rich and they so poor? Solow (1957, 1960) answered that it was because rich countries invested heavily in equipment and education and used these resources productively, while poor countries did not. Solow also illustrated that future knowledge-based economy success depends on education and productivity of the factors of production. He added it is the productivity which explains the major share of the growth phenomenon and differences between the countries in the modern day world. In addition, Romer posed the question, what is the engine of long run economic growth? His model clearly demonstrated that the engine is invention, and that its drivers are entrepreneurs who, for one reason or another, create the stream of new ideas that, taken together, we call technological progress or knowledge-based progress (Jones, 1998).

Thus, we may say the new discipline of economics of knowledge/knowledge-based economy (KBE) is related to an abundance of new ideas rather than the scarcity of natural resources and that knowledge economies generate wealth of nations by using the assumptions of falling costs, efficiency, scale economies, productivity and increasing return. This study investigates the aforementioned concepts in subsequent chapters using suitable empirical methodologies.

2.1 Background of our sample countries

This study initially investigates six selected South East Asian countries (ASEAN-5 plus South Korea) namely Indonesia, Malaysia, the Philippines, Singapore, Thailand, South Korea before later adding more emerging knowledge – based economies in the analysis as the investigations proceed with sophisticated models in subsequent chapters. Recent times have these selected South East Asian countries labelled as growth miracles by many researchers in recent time (Krugman, 1994; Rodrik, Grossman & Norman, 1995). However, the growth miracle of these countries was slowed down due to the financial crisis and has failed to achieve efficiency in using knowledge intensive resources optimally in the late 90s. The Association of Southeast Asian Nations (ASEAN) was originally established by

Indonesia, Malaysia, the Philippines, Singapore, and Thailand in 1967 in Bangkok. Related to the changing geopolitical environment of Southeast Asia in the 1980s and early 1990s, new members joined the Association. Brunei Darussalam joined in 1984, Vietnam in 1995, Laos and Myanmar in 1997, Cambodia in 1999 and South Korea, India and China joined in 2007, thus making it a group of ten countries with an additional three. The ASEAN region has exhibited an impressive economic growth pattern in recent years. However, with the exception of Singapore, none of the original ASEAN-5 countries' growth is currently knowledge driven. According to a recent report by the global research company IHS, ASEAN-5 economies will grow by US$4.7 trillion in 2020 compared to a nominal gross domestic product of US$2 trillion in 2013. This is more than double the expansion of economic growth for this regional bloc in coming years. However, in order to sustain this remarkable growth phenomenon, these selected South East Asian countries must to pursue an innovation driven economy in which growth potential is enormous (Lo, 2003). Theoretically speaking, there are three stages of economic development namely, a. factor-driven economies, b. efficiency driven economies and c. innovation-driven economies. A factor-driven economy is essentially based on the low cost of labour and an abundance of natural resources. The comparative advantage of export depends on the low cost of labour, capital accumulation and availability of natural resources. This was the early growth phenomenon of selected South East Asian countries as described by Paul Krugman (1994). In recent years, Malaysia, Thailand, Indonesia, Singapore and the Philippines have been considered as efficiency driven economies in ASEAN bloc. An efficiency driven economy is essentially an economy whereby a country's comparative advantage relies on producing advanced products, adopting sophisticated technological methods in the production process and efficient service delivery from public and private sectors. Efficiency driven economies are often considered as being at the post catch-up period stage, which demonstrates the country's readiness to transform into an innovation driven or knowledge-based economy (Tan & Hooy, 2007). However, building a knowledge-based economy requires certain critical factors such as a high quality education system, secondary and tertiary higher levels of enrolment, the development of knowledge transfer between university to industry, improved information and communication technology, higher expenditure in R&D, transparency, the development of regulatory quality, availability of venture capital, service sector innovation and overall political stability. Efficient use of these important variables in all sectors of the economy can help these selected South East Asian countries to maintain a long run economic growth trajectory. The growth of an innovation driven economy will not be sustained merely through the production of knowledge intensive goods and services, but rather depends on the efficient organisation of knowledge acquisition, production, distribution and utilisation in all sectors of the economy. The objective of this research is to demonstrate this phenomenon with the application of both quantitative and historical analysis of the frontier country's innovation polices for selected South East Asian countries.

2.2 Current KBE frameworks and a case of Brunei Darussalam

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2.2 Current KBE frameworks and a case of Brunei Darussalam

2.2.1 Current KBE frameworks

The current literature offers few consistent methodological underpinnings with which to measure the knowledge level of a firm, region or economy. Indeed, Leung (2004) notes that there is no internationally agreed framework for measuring a KBE. While the development of indices to measure knowledge is interesting, such indices are generally available only at the national level. More fundamentally they tend to be data-driven (using that data which is available across countries) rather than conceptually-driven e.g. "being based on a model of knowledge acquisition and use and relationships to innovation and economic performance" (Cader, 2008, p.120). Models of Comprehensive Knowledge Expression Assessments are presented by the OECD (from 1996), Atkinson and Court's New Economy Index (1998), the World Bank (2002), the Australian Bureau of Statistics (ABS, 2002), APEC (2000), Harvard University framework and UNECE (Krisciunas & Daugeliene, 2006). The ABS (2002) states that most of these existing frameworks are generally descriptive in nature, that is, they are defined in terms of the statistics presented rather than being derived on the basis of theory or empirical evidence. The objective of this section is to review the various KBE frameworks and highlight some possible shortcomings.

2.2.2 OECD framework

In 1996, the OECD published the KBE project report, an early attempt to compile statistical indicators on KBEs. It published another compilation in 1999 and started releasing results from the two-year Growth Project in 2002. The impetus for the project was to discover the causes underlying differing economic growth rates of member nations during the 1990s. According to the OECD framework, the root of KBE has been formulated by Romer (1986,1990) and Helpman & Grossman (1991), who developed new growth theories with which to explain the forces driving long-term economic growth. According to the neo-classical production function, marginal returns diminish as capital is accumulated in an economy, although this is an effect which may be offset by the flow of new technology. In new growth theory, knowledge can raise the marginal returns on investment, which can in turn contribute to the accumulation of knowledge in a positive loop. It does this by stimulating more efficient methods of production as well as new and improved products and services. There is thus the possibility of sustained increases in investment, which can lead to continuous rises in a country's sustainable growth rate. Knowledge can also spill over from one firm or industry to another, with new ideas used repeatedly at little extra cost. Such spill-over can ease the constraints placed on growth by the scarcity of capital.

The OECD makes the distinction between codified knowledge and tacit knowledge. Codified knowledge is the material, or information, to be transformed into documents, while tacit knowledge refers to the skills and know-how required to handle and interpret codified knowledge. The principal knowledge indicators, as collected and standardised by the OECD, include:

i) expenditures on research and development (R&D);
ii) employment of engineers and technical personnel;

iii) patents; and
iv) international balances of payments for technology.

The OECD Science, Technology and Industry (STI) Scoreboard consists of 76 indicators under five sub-titles: R&D and Innovation (15), Human Resources in Science and Technology (10), Patents (11), ICT (17), Knowledge Flows and the Global Enterprise (12), and The Impact of Knowledge on Productive Activities (11) (OECD, 2005). To sum up, as can also be seen from the dimensions and their indicators in Table-A.1 (Appendix-1), the OECD KBE focus is on interaction and positive externalities in ICT development, science and technology improvement, and increasing globalisation.

Table A.1 (Appendix) shows the indicators developed by the OECD to measure the extent of an economy's knowledge base. The critical view of the OECD framework is that it is data-driven rather than based on sound theoretical concepts. This framework does not consider the inputs and outputs of new growth theory in any significant way, instead selecting only variables under five key pillars.

2.2.3 The Asia Pacific Economic Cooperation (APEC) framework

The APEC (2000) framework was developed as part of a project commissioned by the APEC Economic Committee in mid-1999. The title of the project was *Towards Knowledge-based Economies in APEC* and it was conducted by a specially created KBE Task Force; members of which included Australia, Canada and Korea. The aim of the project was to 'provide the analytical basis useful for promoting the effective use of knowledge, and the creation and dissemination of knowledge among APEC economies' (APEC Economic Committee, 2000). The APEC Economic Committee states that 'the knowledge required by a knowledge-based society is wider than purely technological knowledge; for example it includes cultural, social and managerial knowledge' (APEC, 2000). They argue that there are four basic determinants of KBE for sustainable economic growth, as follows:

a. Business Environment,
b. ICT Infrastructure,
c. Innovation System of research and development,
d. Human Resource Development.

Table A.1 (Appendix A) shows the detailed list of APEC KBE indicators. Under these four key dimensions, many more detailed variables are used to measure the creation, dissemination and use of knowledge in APEC economies. Unlike the OECD and WBI frameworks, which consider many economies, APEC only considers seven APEC case study economies in order to explain KBE. These represent four clusters of APEC economies:

- The Most Developed Economies (with Australia and Canada as case studies),
- High Performing Asian Economies (with Singapore and Korea as case studies),
- Asian Fast-Growing Economies (with Philippines and Thailand as case studies), and

• Latin American Economies (with Chile as a case study).

The case study economies were selected primarily on the basis of data available to the project team and their potential for generalisation to other similar APEC countries only (APEC, 2000). This process thus loses the robustness of applicability of the framework for other countries.

2.2.4 World Bank (WB) Framework

The World Bank Institute (2002) has developed the Knowledge Assessment Methodology (KAM) as a KBE framework for its member states in order to indicate their level of knowledge-based economic development and as a policy input to the achievement of sustainable economic growth. They generally agree with the OECD and APEC frameworks of KBE and state that with sustained use and creation of knowledge at the centre of the economic development process, an economy essentially becomes a Knowledge Economy. A Knowledge Economy (KE) is one which utilises knowledge as the key engine of economic growth. It is an economy where knowledge is acquired, created, disseminated and used effectively to enhance economic development. It has been found that the successful transition to a Knowledge Economy typically involves elements such as long-term investments in education, R&D expenditure, developing innovation capability, modernising the information infrastructure, and having an economic environment which is conducive to market transactions. These elements have been termed the pillars of the Knowledge Economy by the World Bank. More specifically, the four pillars of the Knowledge Economy (KE) according to the WBI framework are:

a. An economic incentive and institutional regime which provides good economic policies and institutions which permit efficient mobilisation and allocation of resources whilst also stimulating creativity and incentives for the efficient creation, dissemination, and use of existing knowledge.
b. Educated and skilled workers who can continuously upgrade and adapt their skills to efficiently create and use knowledge.
c. An effective innovation system of firms, research centres, universities, consultants, and other organisations which can keep up with the knowledge revolution and tap into the growing stock of global knowledge whilst assimilating and adapting it to local needs.
d. A modern and adequate information infrastructure which can facilitate the effective communication, dissemination, and processing of information and knowledge.

The Knowledge Economy framework thus asserts that investments in the four knowledge economy pillars are necessary for sustained creation, adoption, adaptation and use of knowledge in domestic economic production, which will consequently result in higher value-added goods and services. This would, putatively, increase the probability of economic success, and hence economic development, in the current highly competitive and globalised world. The WBI Knowledge Assessment Methodology (KAM) (www.worldbank.org/kam) is based on 83 structural and qualitative variables which serve as proxies for the four knowledge economy pillars: Overall Economic Performance (9), Economic Incentive and Institutional Regime Index (19), Innovation System Index (24), Education and Human Resources Index

(19) and ICT Index (12). There are two frequently used modes of the KAM: The Basic Scorecard and Knowledge-based Economy Index.

The World Bank KAM Basic Scorecard provides an overview of a country's performance in terms of the pillars of the knowledge economy under 5 sub-titles. It includes 14 standard variables: two performance variables and 12 knowledge variables, with 3 variables representing each of the 4 pillars of knowledge economy. Table A.1 (Appendix-A) shows these indicators.

According to the WBI, the knowledge economy can also be quantified by means of a numerical index known as the Knowledge Economy Index (KEI). This is calculated from the data of twelve indicators, each three of which form a single pillar. The KAM Knowledge Economy Index (KEI) is an aggregate index which represents the overall level of a country or region's development as a Knowledge Economy. It summarises the performances of the four Knowledge Economy pillars and is constructed as the simple average of the normalised values of the 12 knowledge indicators of the basic scorecard from 0 to 10. A KEI score which is close to 10 implies relatively good development of the four knowledge economy pillars when compared to other countries, while a score close to 0 indicates relatively poor development. The basic scorecard can thus be seen as a disaggregated representation of the Knowledge Economy Index. A critical and more detailed discussion of KAM will be addressed in Chapter 5, case study-2 section.

In general, all the contemporary KBE frameworks discussed above are constructed using available data and lack rigorous theoretical underpinnings. Moreover, each framework has a specific purpose related to the needs of the organisation's member states. For instance, the World Bank has developed the KAM to show a country's readiness to become a KBE, while the OECD focusses solely on innovation performance in its framework. The aim of the APEC Project was to provide the analytical basis useful for promoting the effective use of knowledge, and the creation and dissemination of knowledge among APEC economies. Comparing these three frameworks, it is obvious that the WBI system is the most comprehensive as it incorporates the important features of the OECD and APEC frameworks whilst also considering KBE indicators across four broad pillars. Although KAM is designed for planners and policy makers engaged in national knowledge assessment, it can be used by anyone with an internet connection. In response to a user's selection, the KAM generates reports which reveal how an economy compares with other countries on various aspects of the knowledge economy. In the World Bank KAM programme, 140 countries are ranked on an ordinal scale, thus indicating the relative performance of countries as a knowledge economy.

The World Bank's internal databases and published datasets are particularly useful for KAM, although a wide range of publicly accessible data are obtained from other organisations as well, among them Freedom House, the Heritage Foundation, the International Labour Organisation, the International Telecommunication Union, the U.S. Patent and Trademark Office, UNESCO's Institute for Statistics, and the World Economic Forum. The KAM on the Web is continuously updated as new data become available. Thus, unlike OECD and APEC, WBI KAM is more inclusive in terms of data sources and number of countries in the world while defining current

KBE frameworks. Therefore, this study considers KAM as a case study in order to discover its pros and cons from a methodological perspective (Chapter 5).

2.3 An alternative, policy-focussed KBE framework

As discussed in Section 2.2, the KBE indicators used by APEC, the OECD and the WBI are data-driven and designed with the interests of the organisations' member countries in mind. Applying them universally across all countries in different regions, at different stages of development and with different institutional, social and economic characteristics may be misleading and result in inappropriate policy responses. In this chapter we propose a framework which clearly distinguishes between input and output indicators of a knowledge-based economy under four important dimensions: knowledge acquisition, knowledge production, knowledge distribution and knowledge utilisation.

The precise variables to be used under each dimension would be determined based on the circumstances of each individual country and availability of data. These variables include perforce, not rigid but rather flexible and could be modified according to the needs of the respective countries. The modified analytical framework is shown in Table 2.1.

Table 2.1: A policy focussed KBE framework

	Knowledge acquisition	Knowledge production	Knowledge distribution	Knowledge utilisation
Input	1.Oppenness (Exports + imports)/GDP 2. FDI inward flows as % GDP	1.Scientific R & D expenditure as % GDP 2.Researchers per 1000 population 3.Intellectual Property Rights (IPR)	1.Education expenditure as % GDP 2. Net enrolment ratio at secondary school 3.ICT spending as % GDP	1.Technological R&D expenditure as % of GDP 2.Business R&D expenditure in total R&D expenditure 3.Knowledge transfer rate 4.FDI inflows %GDP
Output	1.Competitiveness 2.HDI 3.Real GDP growth	Scientific publications per 1000 population	1.Tertiary education per 1,000 population. 2.PC penetration per 1,000 population 3.Internet host per 1,000 population	1.Share of patent applications to EPO total. 2.Exports of ICT products as % of total. 3.Production of High-Tech sector as % of total GDP

With regard to Table 2.1 above, the top section of each box contains input indicators whilst the bottom section of each box contains output indicators of KBE. Explicitly considering the inputs and outputs of knowledge is not new. Many of the innovation case studies from the past twenty years focussed on a relatively small group of R&D-intensive sectors of the economy and emphasised a process of innovation which proceeds via a linear sequence of phases (Smith, 2000).

In this view, innovation begins with new scientific research, which progresses sequentially through stages of product development, production and marketing, and terminates with the successful sale of new products, processes and services (OECD, 1996). However, it is now recognised that sources of innovation are not limited to R&D but can stem from many areas, including new manufacturing capabilities and recognition of market needs. Innovation can assume many forms, including incremental improvements to existing products, applications of technology to new markets and uses of new technology to serve an existing market. Moreover, the process is not completely linear. Innovation requires considerable communication among different actors – firms, laboratories, academic institutions and consumers – as well as feedback between science, engineering, product development, manufacturing and marketing. Hence, innovation can only become possible through the interaction of knowledge acquisition, production, distribution and utilisation together in a Knowledge-based economy. We have chosen our empirical methodologies because of the non-linear nature of the innovation process in subsequent chapters.

As an example of the application of this framework, the potential acquisition of knowledge can be captured by the openness of an economy to the world in trade and foreign direct investment (FDI). The openness of an economy, as an input indicator, is measured as the ratio of a country's trade (exports plus imports) and FDI inflows to its GDP. For an output indicator concerning knowledge acquisition, we use the competitiveness of an economy as estimated by the World Competitiveness Yearbook rank and Human Development Index (HDI) rating. Regarding the production of knowledge, within an economy, imput indicators include the percentage share of expenditure on scientific R&D in GDP and number of researchers whilst scientific publications are used as an output indicator.

Distribution and utilisation of knowledge are the other two basic dimensions of a knowledge-based economy. The distribution of knowledge includes all forms of disseminating or diffusing knowledge by way of information and communication technologies (ICT) and the transmission of knowledge by way of education. For education, expenditures on the levels of tertiary education and the net enrolment ratio of secondary schooling are used as input indicators while tertiary education enrolment is an output indicator. For ICT, expenditure as a percentage of GDP is an input indicator while personal computer (PC) penetration and the number of internet users per 1000 of the population are outputs. For knowledge utilisation, scientific and technological R&D and business R&D expenditure are used as input indicators while patent applications, the shares of ICT production in GDP and exports of the high-tech sector as a percentage of GDP are used as output indicators.

2.4 A case study of a resource-based economy: Brunei Darussalam

In this section we investigate the application of the model developed in Section 2.3 to the case of Brunei Darussalam (hereafter Brunei), which is striving to transform its economy from almost completely resource-based to, at least in part, a KBE. One of the major obstacles when it comes to assessing Brunei's current position in ASEAN as a KBE is the limited amount of available data. This is likely to be the case with many developing nations and requires flexibility in the application of the model; some variables will have to be combined and others dropped or replaced in a pragmatic attempt to gain real insights into the current status of knowledge development in the economy.

2.4.1 Current socio-economic panorama of Brunei

Brunei is a small sultanate on the north coast of Borneo. In 2010, its population was estimated at approximately 414,000; its land area is 5,770 square kilometres and it is bordered by the East Malaysian state of Sarawak. The Brunei economy is largely dependent on oil and natural gas, which in 2009 accounted for 96% of exports, almost 90% of government revenue (Ministry of Finance, 2010) and 60% of GDP (Department of Economic Planning and Development, 2010, Lawrey, 2010a). Brunei is the third largest oil producer in S.E. Asia after Indonesia and Malaysia, and is a major liquefied natural gas (LNG) exporter. The remainder of the economy is dominated by the public sector with very little manufacturing and with agriculture, forestry and fisheries accounting for less than 2% of GDP.

Despite a series of five-year development plans aimed at diversifying the economy, relatively high wages and low productivity make manufacturing uncompetitive and reinforce the dominance of the public sector. It is from this position of a country suffering from Dutch Disease or the resource curse hypothesis that Brunei is looking at the transition from a resource-based economy to a KBE. The most recent development plan includes a National Vision, or *Wawasan Brunei 2035*. In this, the Government has formulated four development thrusts: (i) widening the economic base and strengthening the foundation for a KBE with emphasis on knowledge, creativity and innovation; (ii) accelerating social progress and maintaining political stability to enhance the quality of life, maintain a sustainable and clean environment, strengthen national security and develop a disciplined and caring society; (iii) enlarging the pool of highly-skilled labour force; and (iv) strengthening institutional capacity (Malhotra, 2010). These policy goals are very much in line with the transition from a resource-based to a Knowledge-based economy with the overall goal of long run sustainable development.

In order to demonstrate Brunei's current status regarding knowledge acquisition, production, distribution and utilisation, we adopt the policy focus-framework as follows:

- Knowledge production and distribution combined: under this dimension net enrolment ratio of secondary school students is used as the input variable and internet users per 1000 of the population is considered as an output variable.
- Knowledge acquisition: FDI inflows can be used as an input and HDI ratings as an output variable.
- Knowledge utilisation: R&D expenditure can be used as an input whilst patents, and export of ICT products as a percentage of total exports are considered as an output variable.

2.4.2 Knowledge Production and Distribution

Table 2.2: Net enrolment ratio in secondary schools, 2006-2007 (%)

Country	2006	2007
Brunei Darussalam	90.1	89.1
Indonesia	60.4	67.5
Malaysia	80.8	81.8
Philippines	60.4	61.3
Thailand	71.0	76.1

Source: ADB key indicators-2007, Human Development Report 2006-07, MDG Indicators Report-2009, collected from ASEAN HQ, Jakarta

Table 2.2 above presents data showing that the net enrolment ratio in Brunei of 90.1% in 2006 and 89.1% in 2007 is the highest of the big ASEAN economies. This is a positive input for knowledge production in Brunei.

Table 2.3: ASEAN and selected south-east Asian countries' internet service statistics: 2006-07

Internet users per 1000 population	Brunei	Malaysia	Singapore	Thailand	ASEAN
2006	416.9	542.3	345.9	130.7	96.9
2007	488.2	557.0	692.4	200.3	114.9

Source: ASEAN Connect website; Euro monitor, International Marketing Data and Statistics, 2001; MDG Database as of September 2010, collected from ASEAN HQ, Jakarta

Table 2.3 indicates that Brunei stands third in ASEAN for internet usage, with 488.2 internet users per 1000 of the population in 2007 compared to the ASEAN average of 114.9.

2.4.3 Knowledge Acquisition

Table 2.4: Foreign Direct Investments inflows into ASEAN by host country, 1995-2009 (US $ million)

Country	1995-2009
Brunei Darussalam	10,103.1
Indonesia	40,404.8
Malaysia	68,059.8
Singapore	236,510.2
Thailand	88,079.9
ASEAN	525,159.0

Source: ASEAN Secretariat, ASEAN FDI database as of 30th June, 2010

Table 2.5: HDI 2006-07

Country	2006	2007
Brunei Darussalam	.919	.920
Indonesia	.729	.734
Malaysia	.825	.829
Singapore	.942	.944
Thailand	.786	.783
Philippines	.747	.751

Source: UNDP Development Report websites, July 2005, November 2006, ADB key Indicators 2006, 2007, 2008

As shown in Table 2.4, Brunei has the lowest FDI inflows compared to other selected south-east Asian countries. Singapore stands highest in FDI inflows during the 1995-2009 periods in ASEAN. Moreover, the majority of Brunei's FDI is related to the already well-established oil and gas industry rather than new investment. This is an area of concern for knowledge acquisition. Table 2.5 shows that Brunei has a higher HDI rating in 2006-07 compared to other ASEAN countries. In 2007 Brunei's HDI was .920, leaving it second behind Singapore. The implication is that Brunei has performed well in knowledge acquisition despite low FDI inflows. However, the reality is that Brunei's high HDI ranking is largely due to the revenues from oil and gas exports and associated investments over the last 40 or so years and thus is non-sustainable over the long-term. Moreover, the HDI index is an imperfect measure of the output of knowledge acquisition as it is primarily concerned with the socio-economic development of a country rather than innovation, or a country's information and communication technology status. However, socio-economically speaking, Brunei is certainly in a good position, which is a precondition of KBE development.

2.4.4 Knowledge Utilisation

Table 2.6: ICT goods export (% of total goods exports)

Country	**2007**
Brunei Darussalam	.189 (2006-07)
Indonesia	5.25
Malaysia	41.64
Singapore	36.19
Thailand	22.23
Philippines	58.13

Source: World Development Indicators (WDI), 2010

In the case of knowledge utilisation inputs, Brunei does not have data on R&D expenditure, either from the government or business sector. Moreover, on the output side, there is no data on patents or exports of high tech products. Therefore, we consider ICT goods exports as a percentage of total goods exports to show the knowledge utilisation dimension for Brunei. Table 2.6 shows that Brunei has the lowest ratio of ICT goods export which is only .189% compared to other south-east Asian countries' counterparts like Singapore at 36.19%, Malaysia with 41.64%, and Philippines at 58.13% in the year 2007. As we know, without knowledge utilisation through commercialisation of knowledge intensive products, a country's long run sustainable growth is not possible, nor is the creation of high-wage employment or the generating of higher returns to capital and labour which come along with this growth. Hence, we can say that Brunei is still under-performing when it comes to knowledge utilisation.

2.5 Conclusion, policy implications and future research

The main aim of this chapter is to review the theoretical development of the KBE concept and discuss the concepts and frameworks developed by WBI, OECD and APEC whilst also considering their applicability to an economy like Brunei; an economy which is attempting to develop as a KBE. In this regard our study finds that the origin of the theoretical aspects of knowledge economy starts with the works of Adam Smith (1776), Marshall (1890), Robert Solow (1957), Schumpeter (1942), Machlup (1962), Hayek (1974), Paul Romer (1986) and many others schools of thought mainly under evolutionary and new growth theories. They essentially argued for a laissez-fair economy and an assumption of perfect competition where knowledge can be created by free interaction of society's economic agents. The more open an economy and the more free movement of information and new technology, the better the chance of creating new wealth of nations. However, it was not always true in the case of some Asian miracle countries. The present study will address this issue in Chapters 6 and 7.

With so little private sector activity in Brunei it seems unlikely that a laissez-fair approach will succeed at this stage of the country's development. The problem for Brunei is that the likelihood of "organic" growth occurring in the private sector which is sufficient to make an impact on the macroeconomic performance of the economy appears remote. The challenge at the heart of Brunei's economic performance is that future economic growth depends upon support from the government through continued public expenditure and possibly public private partnerships, although growth is also hindered by a government which exercises too much bureaucratic control, takes away resources from the private sector, and creates a culture of dependency (see Lawrey 2010b).

With regards the use of KBE indicators to guide development policy, this chapter has highlighted the shortcomings related to the use of a universal approach across countries in different regions, at different stages of development and with different institutional, social and economic characteristics. Not only may this approach be theoretically questionable, but it may simply be impossible given the lack of consistent data in many developing countries. The more pragmatic approach used here is to see what data is available under the four WBI pillars and to attempt to make some policy recommendations based on the picture which emerges. In the case of Brunei, there is clearly much work to be done. Figures are unfavourable for Brunei, and particualrly those concerning the dimensions of knowledge acquisition and utilisation. Indeed, although figures are not available for the dimension of knowledge production, Brunei is in fact performing well in HDI and school enrolment figures which are favourable for knowledge dissemination. After all, it is true that the education sector is a focal point of policy in Brunei. In 2008, Sistem Pendidikan Negara Abad Ke-21, (The National Education System for the 21st Century SPN21) was introduced, and brought about major changes to education in Brunei in an attempt to meet the challenges of the 21st century. However, what this exercise has shown is that there is substantially more to becoming a KBE than a good education system. If Brunei is to become a KBE, and if the WBI is even partly relevant for Brunei and countries like it, then policies should be directed at improving knowledge production, acquisition and utilisation. The primary inputs for these indicators are FDI inflows and research and development, both in terms of expenditure and number of researchers. While research funding has increased significantly in 2011 (Brunei Times Feb 11, 2011), it is too early to say if this level of funding will be sustained. Moreover, research capacity at the tertiary education level and in other research centres is very constrained, whilst FDI is essentially non-existent outside the established oil and gas industry. It is in these areas that policy can be directed to increase the knowledge-based component of GDP.

In conclusion, if the WBI and other organisations' KBE indicators are to be useful as a policy tool it is essential to put in place a more rigorous approach to establishing their significance than exists at present. Indeed, there is certainly more work to be done in this area. The subsequent chapters will demonstrate how this empirical study seeks to obtain more meaningful results from these KBE indicators.

As far as Brunei is concerned, this chapter has established that, in as much as the four pillars of the WBI indicators are relevant for transition to a KBE, there is a considerable amount of work to be done, particularly regarding the efficient use of FDI, education expenditure, school enrolment, and research and development (R&D) funding to build an innovation system. These issues will be addressed subsequently.

CHAPTER 3: EMPIRICAL INVESTIGATION OF KNOWLEDGE-BASED ECONOMY (KBE) FRAMEWORKS AND INPUT-OUTPUT INDICATORS FOR ASEAN-5

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3.0 Introduction

The past decade has seen a substantial body of research conducted on productivity-led economic growth and its determinants (Sundac & Krmpotic, 2011). A major reason for this is the widespread belief that economic growth stemming from rapid factor accumulation is subject to diminishing returns and, hence, is not sustainable. Recently, there has been growing interest in the contribution of knowledge to total factor productivity growth and, consequently, to sustainable long-term economic development. In East Asia, especially in the ASEAN (Association of Southeast Asian Nations) region, the awareness and emphasis on KBE began less than a decade ago. The OECD (Organization for Economic Development and Co-operation), APEC (Asia-Pacific Economic Co-operation), WBI (World Bank Institute) and ABS (Australian Bureau of Statistics) have all proposed different KBE frameworks focussing on the best use of knowledge for economic development, under which they suggest different KBE pillars and large sets of KBE indicators.

The motivation for this chapter's research comes from examining the gap in the existing literature, whereby the OECD, APEC, WBI and ABS studies propose a large number of KBE variables and suggest investing in those indicators in order to become a KBE (Fen & Chaudhry, 2006). However, it would be financially unsustainable and unfocussed for countries to invest in all of the variables proposed by the OECD, APEC, WBI and ABS. As such, it would be useful for a government to know which factors of the knowledge economy are the best contributing factors to a country's economic progress. In order to achieve this we consider five selected south-east Asian countries, namely Indonesia, Malaysia, Singapore, the Philippines and Thailand as study countries. We also propose a policy-focussed KBE framework based on the definitions of the OECD, APEC and WBI. This study uses some critical assumptions to choose important variables out of large sets of KBE indicators and apply the beta coefficient technique to investigate the best contributing indicators behind the successful countries in the south-east Asian region when it comes to the transition towards KBEs. While the literature on knowledge management and national innovation systems encompasses many disciplines, this chapter focusses on a specific economic approach to the topic.

We divide our chapter based on two methodologies. The first part discusses beta coefficient techniques and unveils important KBE input-output indicators for selected south-east Asian countries (ASEAN-5 countries). The next part will discuss the productivity performance of these economies in transition towards a knowledge economy using Malmquist productivity index.

3.1 Literature review

In order to promote economic, cultural and political cooperation in the region, the ASEAN group comprising Indonesia, Malaysia, the Philippines, Singapore and Thailand, was established in 1967, with Brunei, Myanmar, Laos and Vietnam joining later. From the inception of the ASEAN, it was claimed that the high-growth phenomenon of the East Asian economies was not sustainable because their expansion was derived from massive inputs of labour and physical capital rather than from gains in technological efficiency (Taylor, 2007). The reason for the inefficiency of the high-growth process lies with the fact that labour and capital are subject to diminishing returns (Romer, 1986, 1990; Helpman & Grossman, 1991).

According to the OECD KBE framework, the root of a knowledge economy has been formulated by Romer (1986) and Helpman & Grossman (1991) who developed *new growth theories* to explain the forces which drive long-term economic growth. In the neo-classical production function, returns diminish as more capital is added to the economy, although this effect may be offset by the flow of new technology. According to new growth theory, knowledge can raise the returns on investment, which can in turn contribute to the accumulation of knowledge. It does this by stimulating more efficient methods of production as well as new and improved products and services. There is thus the possibility of sustained increases in investment, which can lead to continuous rises in a country's growth rate. It has been found that a successful transition to the knowledge-based economy typically hinges on efficient investments in education, public research and development expenditures, developing innovation capability, modernising the information infrastructure, and having an economic environment which is conducive to market transactions (WBI, 1999). These elements have been termed by the World Bank, OECD, ABS and APEC as the pillars of the knowledge economy and together they constitute the knowledge economy framework.

The concept of the KBE was first introduced by the OECD, and was defined as an economy which is *directly based on the production, distribution and use of knowledge and information* (OECD, 1996). Later APEC referred to KBE as *an economy in which the production, distribution and use of knowledge is the main driver of growth, wealth creation and employment across all industries* (APEC, 2000 and 2004). These models describe the environment necessary for the KBE and the indicators used to measure the various characteristics of the environment. While doing so, in its report on the Growth Project (OECD, 2002), the OECD emphasised the importance of a stable and open macroeconomic environment with effective functioning markets; diffusion of ICT; fostering innovation; development of human capital; and stimulating firm creation. Under these core KBE dimensions they proposed a large set of indicators.

The APEC report strives to provide the analytical basis which can be used to promote the effective use of knowledge, and the creation and dissemination of knowledge among APEC economies (APEC, 2000). The Australian Bureau of Statistics (ABS) framework (2002) was developed to measure knowledge in the Australian economy and society. The framework draws on the work of the APEC Report (2000) and the OECD Model (1996), although it explicitly includes the concept of knowledge based society because of the presumed importance of societal factors and the potential positive and negative impacts on society with the increasing emphasis on knowledge. The World Bank Institute (1999) has developed the Knowledge Assessment Methodology (KAM) as a KBE framework for its member states in order to indicate their level of knowledge-based economic development and as a policy input to the achievement of sustainable economic growth. The WBI defines KBE as an economy where knowledge is acquired, created, disseminated and used effectively to enhance economic development. The WBI Knowledge Assessment Methodology (KAM)[1] is based on 83 structural and qualitative variables which serve as proxies for the four knowledge economy pillars: Overall Economic Performance (9), Economic Incentive and Institutional Regime Index (19), Innovation System Index (24), Education and Human Resources Index (19) and ICT Index (12).

These models and frameworks have one common trait, in that they all give a basic analysis of the environment which a KBE should possess and claim that a successful KBE should have the four core dimensions, namely, knowledge acquisition, knowledge production, knowledge distribution and knowledge utilisation. However, it is interesting that none of the current methodologies explicitly divide the KBE indicators under these four core dimensions. Indeed, that is the approach adopted in this section and previous chapter *viz.* to segregate the available KBE indicators under these four dimensions as knowledge input-output indicators for a better understanding of the performance of a KBE (see, for example, Lee, 2001; Tan, Hooy, Manzoni & Islam, 2008 & Karahan, 2011). To build our policy-focussed KBE framework which is presented in the Appendix Table A.2 we select the variables under some assumptions.

We consider the assumptions following the ABS framework (2002) to pick a set of input-output KBE variables out of a large number of indicators. The assumptions are that the indicators should:

1. be relevant to the characteristics they are intended to describe (including policy relevant)
2. be supported by reliable and timely data
3. be sensitive to the underlying phenomena which they purport to measure
4. be intelligible and easily interpreted
5. preferably be available for several time periods including recent periods and
6. preferably be available for other study countries as well, for the purposes of international comparison.

Under these assumptions the relevant variables in the dimensions might be replaced with others over time due to the constant changes in KBEs. Indicators used in the past may no longer be appropriate as an economy progresses. Therefore, the KBE variables are flexible, rather than rigid in nature (Fen & Chaudhry, 2006). It is possible to add more variables if they fulfil the above criteria to show the performance of a KBE. It is important to note that all the variables may not be the best contributing variables for all countries. According to Chen (2008), traditional economy indicators like GDP and GNP are often criticised due to ignorance of socio-

[1] (www.worldbank.org/kam)

[2] Guellec and van Pottelsberghe (2001) define public R&D as R&D performed by government and higher education sectors, and foreign R&D as business R&D performed in other 15 OECD countries.

cultural factors like the enrolment ratio for secondary education, total education expenditure, ICT users etc. There are many flaws in assessing a country's KBE performance by the traditional economy indicators, including a lack of KBE input-output variables. Hence, we can say that KBE is a broad concept which must be addressed from all dimensions of knowledge i.e. creation, acquisition, distribution and utilisation.

Table A.2 (Appendix A) is an example of variable segregation out of many KBE indicators depending on data availability. Many of the factors listed above define the knowledge economy and its effect on entrepreneurial activities and economic development (Kassicieh, 2010). For instance, Derek, Chen & Dahlman (2004) emphasised that education and skilled workers are key to efficient knowledge dissemination, which tends to increase productivity when shared by information and communication technology (ICT) infrastructure. ICT infrastructure refers to the accessibility of computers, internet users, mobile phone users etc. Accordingly, we consider education expenditure and the school enrolment ratio as an input variable and computer users per 1000 of the population as the output variable for the knowledge distribution dimension.

The World Bank Institute (1999) has stated that an effective innovation system depends on research and development (R&D) expenditure, foreign direct investment (FDI) inflows, and knowledge sharing between universities and industry. These variables are often considered as knowledge utilisation inputs in order to produce domestic knowledge intensive products in a national innovation system (Poorfaraj, Samimi & Keshavarz, 2011). Hence, we consider FDI inflows and the knowledge transfer rate as input variables whilst high-tech exports as a percentage of total export is taken as the output variable in the knowledge utilisation dimension.

In many developing countries, knowledge and technology are nurtured from foreign sources and enter the country through FDI, imports of equipment and other goods which are promoted by trade openness and licencing agreements (Poorfaraj, Samimi & Keshavarz, 2011). These variables can make an enormous contribution to economic growth provided there exists a sound, transparent legal and regulatory system in the individual countries. With this in mind, we consider FDI, trade openness, transparency and legal and regulatory quality as inputs, while real GDP growth is the output variable in the knowledge acquisition dimension.

Dahlman & Andersson (2000) have stated that East Asian economies are weak when it comes to innovation activities compared to other, advanced economies, which account for nearly 90% of global R&D expenditures and approximately the same proportion of patents granted and scientific and technical papers produced. They also argue that stronger protection of intellectual property rights enhances the efficiency of innovation systems in a KBE. Hence in our policy focussed framework, we include these variables under the knowledge production dimension. In subsequent sections we will illustrate the best performing countries among the ASEAN-5 nations in each KBE dimension using raw data and investigate the most important KBE input variables behind their success under these dimensions using the standardised beta coefficient technique.

3.2 Methodology for finding important KBE variables for selected south-east Asian countries

This study uses the simple beta coefficient method to investigate the important factors contributing to a KBE. Instead of finding significant variables from simple linear regression models, this method uses the variables' standard deviations to estimate the beta coefficient. According to Chen (2008), the KBE indicators proposed by the OECD, WBI, APEC and ABS differ from one another in terms of indices description, measured categories and measured variables. As such, we use the standardised beta coefficients - a well-known and stabilised methodology used to overcome the problem of variation in measurement units. Standardised beta coefficients refer to how many standard deviations a dependent variable will change, per standard deviation increase in the predictor variable. Standardisation of the coefficient is usually done to answer the question of which independent variables have greater effects on the dependent variable in a multiple regression analysis, when the variables are measured in different units (Gujarati, 2004, Rubinfeld & Pindyck, 1997). Hence, standardised coefficients describe the relative importance of the independent variable in a multiple regression model to ascertain the contributing indicators in each knowledge dimension. We consider the period 1995-2010 while using the beta coefficient technique to rank the significant input variables. In order to calculate the beta coefficient, we first set some linear regression models for each dimension. In our study, all data are collected from secondary sources, including the WDI, WCY and ASEAN statistical yearbooks. The equations are:

Knowledge acquisition dimension:
GZGDP = β1+ β2 OPENNESS +β3 FDI + β4 LRQUA+ β5 TRANS
Knowledge production dimension:
STAR = β1+ β2 RDEXP+ β3 IPR
Knowledge distribution dimension:
COMPUSE = β1+ β2 EDUEXP +β3 SECONDEN
Knowledge utilisation dimension:
HITECHEXPO = β1+ β2 KNOWTRANS+ β3 FDI

Here, the data sources of input variables:
OPENNESS= Trade openness rate (Penn table, 2010)
FDI= FDI inflows % GDP (World Development Indicators, WDI-2010)
LRQUA= Legal and regulatory quality (World Competitiveness Yearbook, WCY-2011, IMD WCY executive survey based on an index from 0 to 10)
TRANS = Transparency of government policy is satisfactory (WCY-2011, IMD WCY executive survey based on an index from 0 to 10)
IPR = Intellectual property rights are adequately enforced (WCY-2011, IMD WCY executive survey based on an index from 0 to 10)
RDEXP = Research and development expenditure % GDP (WDI-2010, WCY-2011)
EDUEXP = Education expenditure % of GDP (WCY-2011)
SECONDEN = Secondary enrolment % of total (WDI-2010, WCY-2011)
KNOWTRANS = Knowledge Transfer rate from university to industry (WCY-2011 executive survey based on an index from 0 to 10)

Data sources of output variables:
GZGDP= Growth of real GDP (WCY-2011)

STAR = Number of Scientific and technical Journal articles per year (WDI-2010)
HITECHEXPO = High-tech export % of Total export (WCY-2011)
COMPUSE= Computer user per 1000 of population (WCY-2011)
We run the regression with the above linear models in e-views software and determine each coefficient value. Using descriptive statistics option in e-views, we obtain the standard deviations of each dependent and independent variable for each equation.

We then apply the beta coefficient technique for each equation by

Beta coefficient, $\hat{\beta}_{\dot{n}} = \hat{\beta}_n \frac{SDX_n}{SDY}$

Here, n = 2, 3, 4, 5, ...k
SD= Standard deviation
Y= dependent variable
X= independent variable

We apply all of these linear equations for each selected south-east Asian country and ascertain the beta coefficient values for each independent variable which we consider as KBE input variables on output variables that are dependent variables. We ignore the sign and focus on the value of each independent variable to rank the contributing input factors on output for each study country.

3.3 Results and discussion

In this section we represent the performance of the selected south-east Asian countries in terms of KBE output variables and subsequently show the most important input variable behind their success over time using the beta coefficient calculation results. The performances of selected south-east Asian countries in terms of KBE output variables are revealed by using raw data for the years 1995 and 2010 as shown in Tables 3.1 through 3.4. We apply all of these linear equations for each selected country and establish the beta coefficient values for each independent variable which we consider as KBE input variables on output variables which are dependent variables. We ignore the sign and focus on the value of each independent variable to rank the contributing input factors on output for each study country.

Table 3.1: Real GDP growth

Economy	1995	2010
Indonesia	8.20	5.80
Malaysia	9.80	7.20
Singapore	8.00	14.10
Philippines	4.70	7.30
Thailand	9.30	7.80

Source: World Development Indicator, 2011

We consider real GDP growth as the output variable of the knowledge acquisition dimension. As shown in Table 3.1, Malaysia, closely followed by Thailand, was the best performer i.e. achieved the highest GDP growth in 1995, while Singapore outperformed all of the countries, having almost doubled their real GDP growth in 2010. This implies that Singapore tremendously improved in this dimension over the years. The question here seems to be, what is the most important factor behind the success of Singapore in this dimension? It is hoped that we can gain some insight into this by observing standardised beta coefficient results in the later part of this section.

Table 3.2: Scientific and technical journal articles

Economy	1995	2010
Indonesia	129.5	200.75
Malaysia	365.8	880.0
Singapore	1141.4	3901.6
Philippines	144.7	197.0
Thailand	339.6	1827.40

Source: World Development Indicator, 2011

Table 3.2 presents the performance results of the knowledge production dimension. Here we use scientific and technical journal articles per 1000 of the population as the output variable and R&D expenditure as a percentage of GDP and intellectual property rights (IPR) as input variables. All the countries have improved their performance by increasing the numbers of articles published over the years which can be considered as the generation of new ideas in a KBE. Singapore and Thailand have shown substantial increases in this area between 1995 and 2010. It could be expected that R&D expenditure will be shown to be more important than IPR in beta coefficient results for all the countries.

Table 3.3: Number of computers per 1000 people

Economy	1995	2010
Indonesia	4.80	42.51
Malaysia	53.94	337.59
Singapore	207	827.48
Philippines	8	81.21
Thailand	18	122.61

Source: Computer Industry Almanac (Updated: JUN 2011), extracted WCY-2011

Table 3.3 shows the knowledge distribution performance of the ASEAN-5 in terms of computer users per 1000 of the population. In this dimension, Singapore and Malaysia are the consistent performers in both years. The beta coefficient results will tell us the most important input variable behind their success.

Table 3.4: High-technology exports (% of manufactured exports)

Economy	1995	2010
Indonesia	7.22	13.20
Malaysia	46.10	48.11
Singapore	53.92	50.01
Philippines	36.80	65.65
Thailand	24.45	27.17

Source: World Development Indicator, 2011

Table 3.4 shows performance in the knowledge utilisation dimension. In this dimension, Indonesia is the lowest performing country while the Philippines show a remarkable improvement in 2010 compared to 1995. Our study considers two input variables in this dimension, namely FDI inflows as a percentage of GDP and the knowledge transfer rate from university to industry. We will show the most important variable behind the success of the Philippines.

Table 3.5: Beta coefficient values of KBE input variables

KBE Dimension	***Input factors***	Malaysia	Indonesia	Singapore	Philippines	Thailand
Knowledge acquisition	LRQUA	0.15	0.65	0.14	0.42	0.087
	TRANS	0.04	0.51	0.14	0.40	0.42
	FDI	0.66	0.83	0.34	0.07	0.68
	OPENNESS	0.20	0.59	0.14	0.59	0.43
Knowledge Production	RDEXP	0.80	0.53	0.66	0.32	0.85
	IPR	0.23	0.13	0.30	0.13	0.73
Knowledge Distribution	EDUEXP	0.33	0.14	0.017	0.70	0.11
	SECONDEN	0.60	0.96	0.64	0.01	0.61
Knowledge Utilisation	KNOWTRANS	0.29	0.22	0.54	0.51	0.68
	FDI	0.22	0.38	0.24	0.15	0.21

Table 3.6: Ranking of KBE input variables from Beta coefficient results

KBE Dimensions	***Input factors***	Malaysia	Indonesia	Singapore	Philippines	Thailand
Knowledge acquisition	LRQUA	3	2	2	2	4
	TRANS	4	4	2	3	3
	FDI	1	1	1	4	1
	OPENNESS	2	3	2	1	2
Knowledge Production	RDEXP	1	1	1	1	1
	IPR	2	2	2	2	2
Knowledge Distribution	EDUEXP	2	2	2	1	2
	SECONDEN	1	1	1	2	1
Knowledge Utilisation	KNOWTRANS	1	2	1	1	1
	FDI	2	1	2	2	2

Table 3.5 shows the standardised beta coefficient values from the multiple linear regression analysis while Table 3.6 ranks KBE input variables according to the beta

coefficient values for each country. To understand the beta coefficient values we represent the knowledge acquisition dimension result of Indonesia as an example. All other results will be provided on request to the corresponding author.

Table 3.7: The regression results of the knowledge acquisition dimension for Indonesia (including the regular and the standardised coefficients)
(Dependent variable: real GDP growth (GZGDP))

Variable	Coefficient	Standardised beta coefficient	T statistic (for std. coefficient)	Prob.
FDI	2.4	0.83	3.28	0.0073
OPENNESS	0.40	0.59	2.43	0.033
LRQUA	3.75	0.65	2.08	0.06
TRANS	2.85	0.51	1.68	0.12

The coefficients in the second column of Table 3.7 demonstrate the effect of a unit change in each of the independent variables on the dependent variable. However, it is hard to compare the importance of the independent variables in determining real GDP growth (GZGDP), since the units of measurement vary. The standardised beta coefficients, in the third column, are more appropriate for this purpose. The most important determinant of the GZGDP is FDI inflows as a percentage of GDP (the standardised coefficient is the highest of all the independent variables). The two variables are both positive and statistically significant. All other remaining variables and their respective dimensions follow the same pattern. Hence, Table 3.6 ranks the independent variables (KBE inputs) according to the standardised beta coefficient values in each knowledge dimension for the ASEAN-5. The results indicate remarkable consistency among countries and some interesting exceptions. For knowledge acquisition, FDI ranks as the most important input indicator for all countries except the Philippines, for which it is the least important of the four inputs considered. For the Philippines, openness is estimated to be the most important input. For knowledge production, R & D expenditure is the most important input for all 5 countries; and for knowledge utilisation, the transfer of knowledge from universities to industry was most important for all countries except Indonesia. Finally, for knowledge distribution, secondary school enrolment was most important for all countries with the exception of the Philippines.

Considering results by country, for Malaysia, in terms of knowledge acquisition, FDI ranked highest as an input dimension followed by openness, legal & regulatory quality (LRQUA) and transparency (TRANS) in their effects on real GDP growth. This is supported by the fact that in Malaysia, FDI, openness and manufactured exports (especially high technology products) have played an important part in generating significant economic growth over the last three decades (Yusof & Bhattasali, 2008*)*. In terms of knowledge distribution, the high secondary school enrolment ratio was of greater importance compared to total education expenditure in terms of impact on PC penetration. In the case of knowledge utilisation, Malaysia had a high rate of knowledge transfer between universities to industry, which in turn increases high-tech export growth. This was found to be more important than FDI for this particular dimension. For knowledge production, as measured by scientific publications per 1000 of the population, research and development expenditure was ranked as the most important input variable.

In Indonesia, FDI was the most significant contributor to knowledge acquisition like the other fast growing selected south-east Asian nations. It is interesting to see that legal and regulatory quality was found in second position, ahead of openness in the same dimension. This implies a favourable environment for international investment in Indonesia. Secondary school enrolment ratio was high in Indonesia, which generates human resources in the knowledge distribution dimension. However, there was a low rate of knowledge transfer from university to industry in the knowledge utilisation dimension. This might indicate that Indonesian knowledge workers are less innovative relative to those in the other countries. Certainly, the country is becoming increasingly dependent on FDI for generating new ideas and innovation than on internal knowledge transfer.

In Singapore, FDI was the highest contributing factor for knowledge acquisition. Others factors in this dimension received equal ranking. Singapore had high secondary school enrolment, which contributes to building a skilled workforce. It also had an innovative workforce which is captured by a higher knowledge transfer rate in the knowledge utilisation dimension compared to FDI inflows. Unlike other selected south-east Asian countries, for the Philippines openness was the highest contributing factor for knowledge acquisition. This was followed by legal and regulatory quality, transparency and FDI. The Philippines had high education expenditure which is shown in the knowledge distribution dimension whilst its knowledge transfer rate was also high in the knowledge utilisation dimension. This implies that the Philippines is making good use of its education expenditure in order to produce new knowledge and ideas in the universities which eventually transfer this knowledge to high-tech industrial growth. With regard to Thailand, the interesting point in the knowledge acquisition dimension was the lowest ranking of legal and regulatory quality. According to the World Bank Institute governance indicators 2005, Thailand received 63.9 points from 100 in regulatory quality (a higher value indicates strong regulatory quality). Moreover, Freedom House ranking for 2007 showed that Thailand got 7 in political rights in a range of 1-7 (lower value indicates a good system of political rights whilst a higher value indicates bad system political rights) compared to other East Asian nations. The country also scored 5 out of 10 (higher value indicates positive democratic development) points when it came to the stability of democratic institutions variable in the Bertelsmann transformation Index-2006 (http://www.demcoalition.org/pdf/H_Thailand.pdf). Political instability seems to have been the root cause of Thailand's weaker legal and regulatory quality over the past decade.

In our analysis, legal and regulatory quality received the lowest ranking for Thailand compared to FDI, and openness and transparency. For knowledge distribution and knowledge utilisation, education expenditure and knowledge transfer were ranked first respectively. In summary, the results showed that FDI and openness in knowledge acquisition, R&D expenditure in knowledge production, secondary school enrolment in knowledge distribution and knowledge transfer rate in knowledge utilisation dimensions are generally the most important KBE factors of selected south-east Asian countries. Moreover, we can say that the recent success of Singapore in knowledge acquisition, production and distribution, as well as the Philippines' success in knowledge utilisation dimension depend on:

- Efficient use of FDI inflows

- Optimum use of R&D expenditure
- An increase in the secondary school enrolment ratio
- An increase in the interaction between academia and industry, which facilitates the creation and commercial use of knowledge.

The weaker performers like Indonesia can use these findings and invest accordingly in order to become a successful KBE in south-east Asia as well as in the world. The results of our analysis have interesting policy implications for the promotion of sustainable knowledge and economic growth in the south-east Asian region. We wish to stress that the findings of the study are critically based on the choice of KBE variables, and hence, the policy implications discussed here should be considered within this perspective. This study has built a policy focussed KBE framework which clearly shows the input-output indicators of KBE under certain assumptions. Following this, and through use of the Beta coefficient method, it has identified the ranking of KBE input to output variables for the selected south-east Asian countries. It is hoped that this work provides some insight into research strategies which might aid policy formation into KBE investments for long run sustainability.

The results showed that FDI and trade openness in knowledge acquisition, R&D expenditure in knowledge production, secondary school enrolment in knowledge distribution and knowledge transfer rate in knowledge utilisation dimensions are generally the most important factors for the selected south-east Asian nations. We consider the 1995-2010 time periods to show the performance and determine the most important KBE variables for individual and successful countries. Data are mostly collected from secondary sources like WDI, WCY etc. The recent data showed that Singapore, in the first three KBE dimensions, and the Philippines in the knowledge utilisation dimension are the best performers. Indonesia on the other hand showed weak performance in almost all the dimensions. Indeed, Indonesia and other weak performing countries can learn lessons from the success of Singapore and the Philippines, such as the need to improve the efficiency of their FDI inflows, to optimise the use of R&D expenditure, to increase the secondary school enrolment ratio and finally to increase interaction between academia and industry; the latter of which facilitates the creation and commercial use of knowledge. Interestingly, these findings indicate that policy recommendations for the selected south-east Asian countries may not be that unique compared to those for other developing countries.

In light of this, the present study further investigates the production function and factors of conventional and knowledge based productivity growth, efficiency in all knowledge dimensions, scale economics and variation of efficiency over the years using these important knowledge input-output variables. The subsequent chapters follow a growing sophistication of the quantitative methodologies while investigating productivity, efficiency, scale economics and innovation policies of selected emerging knowledge economies.

3.4 The position of conventional and knowledge-based productivity growth in selected south-east Asian countries

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This section aims to investigate the theoretical application of productivity lead knowledge-based growth in selected south-east Asian countries using the advance quantitative productivity analysis technique. It also demonstrates the scale economies, difference between factor accumulation growth and knowledge intensive growth patterns in these countries over the years. The subsequent chapters will investigate the empirical application of efficiency-driven growth in knowledge economies, scale economies and evolutionary theories in national/regional innovation systems.

In this section, we apply the Malmquist Productivity Index to ascertain the stand in conventional Cobb-Douglas production function and the knowledge economy growth in selected south-east Asian countries. These countries, and particularly Indonesia, Malaysia, Philippines, Singapore, South Korea and Thailand, are considered an Asian miracle because of their phenomenal economic growth in recent years. However, in 1994 Young first investigated this growth miracle of South East Asian countries and ranked the Asian countries according to total factor productivity change. He showed in his study that Taiwan, South Korea, Japan and Singapore have higher factor accumulation growth than other south-east Asian countries. However, in 1994 Young revealed that many East Asian economies have significantly lower TFP growth values compared to those in industrial economies. TFP growth in Singapore, for instance, was estimated at 0.2% for 1986-90. Young's findings were consistent with studies conducted by Yue (1999) and Kim & Lau (1994).

In the subsequent application of the growth accounting approach, Taylor (2007) indicated that almost all of Singapore's output growth in 1966-80 could be the reason behind an increase in the quantities of factor inputs, and particularly labour input rather TFP growth. He added in his book that during this time period Singapore was highly dependent on conventional factors of production to generate higher economic growth rate.

Kim & Lau (1994) presented several reasons for the lack of measured growth in productivity efficiency over time for the newly industrialised countries (NICs) in the late 1950s and 60s. Firstly, there is the possibility of scale effects which are difficult to measure with the conventional econometric growth accounting approach. Second, research and development was relatively unimportant in the East Asian NICs due to the lack of investment in public R&D expenditure as well as the scarcity of indigenous technological improvements. Thirdly, the rapid capital deepening in the NICs is not knowledge-intensive nor ICT driven. Finally, poor natural and particularly human resource endowment may have reversed the potential gains in technical progress.

In our study we initially use the conventional Total Factor Productivity formula before using the non-parametric test to gauge the consistency of TFP growth between parametric vs. non-parametric. We briefly highlight the results here.

The Cobb-Douglas production function can be expressed as $\mathbf{Y = A * L^{a} * K^{(1-a)}}$

One of the known methods for parametric estimation is the Ordinary Least Squares (OLS) method (Taylor, 2007). Estimation and calculation by Cobb-Douglas production function has been carried out in this first part of the analysis by collecting data pertaining to real gross domestic product (GDP), gross fixed capital formation (GFCF) as a percentage of GDP represents capital (K), total labour force (15-64 years) as L, and secondary school enrolment as a percentage of total school age population represents the human resource (A) endowments during 2005-2010. The functional form looks like, $\boldsymbol{LGDP = \alpha + \beta_{1LnL} + \beta_{2LnK} + \beta_{3LnSe} + \mu}$ and we are interested in the intercept α which represents the scalar A. Taking each α value for every country, we take the antilog and find the value of scalar A. For each country we run the same regression with the same set of variables and time period. Our results show that the Philippines has a 3.8 intercept value, ranking it first compared to the other six economies. South Korea and Thailand had intercept values of 3.46 and 3.09, with ranks of second and third respectively. On the other hand Singapore and Malaysia score 3.01 and 2.05 respectively during the time span. However, Indonesia had an intercept value of 1.9, meaning that it is a less successful country among the sample countries during our referred years while converting input to output factors of production. We are expecting a similar kind of ranking when we apply the DEA MPI method in Cobb-Douglas production function analysis. We find that it is difficult to capture scale effect through the parametric regression analysis, as as such we apply a non-parametric DEA MPI test to analyse the TFP growth in ASEAN-5 plus one.

3.4.1 Total Factor Productivity (TFP) analysis for selected south-east Asian countries using Malmquist index technique

The early 1990s saw a restoration of the neoclassical growth framework to explain the economic miracle of East Asia with a particular emphasis on Total Factor Productivity Growth (TFP) (Taylor, 2007; World Bank, 1993; Krugman, 1994; Young, 1994). The findings of many studies (e.g. Kim & Lau, 1994; Young, 1994; Krugman, 1994) indicated that the levels of growth experienced by the East Asian economies are the result of high accumulation of both capital and labour with little or no role played by technological progress. In short, growth for many of the south-east Asian countries is input driven rather than productivity driven. This implies that the growth of many East Asian economies will cease as soon as diminishing returns set in. Therefore, it is not sustainable in the long run. Under such circumstances, without technical progress i.e. moving towards Knowledge-based economy (KBE), the growth potential of these economies will be limited. The advantage of KBE over a production based (P-Based) economy centres around the fact that the former is considered an economy where knowledge, creativity and innovation play an ever-increasing and important role in generating and sustaining growth. In contrast, a P-based economy plays a less important role in growth. Growth is driven much more by the accumulation of the factors of production of land, labour and physical capital in a P-based economy (Afzal & Lawrey, 2012a, 2012b).

The growth of human capital and Information and Communication Technology (ICT) is the essence of a Knowledge economy. Thus, the motivation for this study is to investigate the current state of conventional total factor productivity growth (TFP) i.e. the Cobb-Douglas production function[i] and Knowledge economic growth in selected countries of ASEAN in order to help policy formulation to promote ICT and human capital investment. The development of ICT and human capital investment can support the effective use of technology and innovation. In order to achieve the above-mentioned objective, we employ Malmquist Total Factor Productivity (TFP) indexes for a sample of ASEAN countries, namely, Malaysia, Indonesia, Philippines, Thailand, Singapore and South Korea. This technique allows us to further decompose the Malmquist TFP index into three components: (a) efficiency changes due to technological shifts, (b) efficiency changes due to pure technical efficiency, and (c) effects of economies of scale. We calculate the conventional Cobb-Douglas production function and the growth of knowledge economy by using the Malmquist productivity index to exhibit the current stand of selected south-east Asian countries. We break down this part of Chapter 3 into four major sections. For instance, Section 1 provides the introduction, with Section 2 describing the research framework, sources of data, and Malmquist methodology. The results and discussion are then presented in Section 3, following which Section 5 draws conclusions and puts forth policy suggestions.

3.4.2. Research framework

In this study we first calculate the conventional Cobb-Douglas production function using real gross domestic product (GDP), gross fixed capital formation (GFCF) as % GDP, total labour force (15-64 age population), and secondary school enrolment as % of total. The output for the DEA Malmquist Index analysis comprises real GDP, whereas the inputs comprise GFCF, total labour force, and secondary school enrolment as % of total.

Data are collected from World Competitiveness Yearbook (WCY)-2010, World Development Indicators (WDI)-2010 and ASEAN statistical yearbooks. Secondly, in order to measure Knowledge economy productivity, we consider education expenditure and the school enrolment ratio as an input variable and computer users per 1000 of population as the output variable. Indeed, whether it be the OECD (1996), WBI (1999), or Derek, Chen & Dahlman (2004), there has been huge emphasis placed on the notion that education and skilled workers are key to efficient knowledge dissemination which tends to increase productivity when shared by an information and communication technology (ICT) infrastructure. ICT infrastructure refers to the accessibility of computers, internet users, mobile phone users etc. The sample period for this study spans from 2005-2010; a total of 6 years. Subsequently this study measures both Cobb-Douglas and knowledge economy productivity using the Malmquist index for selected ASEAN countries.

3.4.2.1 Malmquist Productivity Index (MPI) methodology

The Malmquist productivity analysis uses panel data in order to calculate total factor productivity change, technological change, technical efficiency change, pure technical efficiency change and scale efficiency change. Fare, Grosskopf & Lovell (1994) provided a detailed discussion of this decomposition. Our main focus is to explain the methodology in a more non-technical way so as to facilitate easier understanding of the method.

Malmquist indexes do not require input or output prices in their construction, and are also unit independent. They are easy to compute, as demonstrated by Fare et al. (1994). MPI is capable of accommodating multiple inputs and outputs without worrying about how to aggregate them. An attractive feature of the Malmquist productivity index is that it decomposes into two components – technical efficiency change and technological change (Fare et al. 1994). Efficiency often refers to the optimum use of input to produce a given level of output. In the Malmquist productivity index, technical efficiency means an optimal combination of the organisation's inputs and outputs. It also refers to the mechanism of catching up with its own frontier for inefficient DMUs with optimum use of input-output factors. Another way in which MPI measures efficiency is by calculating the technological improvement of the DMUs. This means that the frontier is shifting up over time due to technological development. The importance of this decomposition provides the understanding of the sources of productivity change in more detail.

The original MPI assumes constant returns to scale for the production process. As a result, the original MPI typically overestimates productivity change if the production process displays decreasing returns to scale (or underestimates it for increasing returns to scale). To cope with the issue of variable returns to scale, Fare et al. (1994) recommended the use of a generalised MPI which includes an additional component, called scale index, to represent such an effect of economies of scale on productivity. Scale efficiency refers to the extent to which an organisation can take advantage of returns to scale by altering its size towards optimal scale.

One way in which to measure a change in productivity is to consider output expansion given input constraints. However, an alternative could be to reduce the input use, given the need to produce a certain level of output under a reference technology. These two approaches are referred to as the output-oriented and input-oriented measures of change in productivity respectively (Coelli, 1996). This study concentrates on the output-oriented Malmquist productivity index. The Malmquist DEA approach derives an efficiency measure for one year relative to the prior year, while allowing the best frontier to shift. A value greater than unity will indicate positive total factor productivity growth, whereas a value lower than unity will indicate productivity retrogress.

3.4.3 Empirical results

Table 3.8 presents the geometric means of the MPI for each country and the breakdown of its MPI into five components: technical change (Effch), technological change (Techch), pure efficiency change (Pech), scale change (Sech) and total factor productivity change (Tfpch). In the first table we use the component of the Cobb-Douglas production function, for instance population 15-64 age as labour force, gross capital formation as % GDP as capital, secondary school enrolment as % total as human capital as input variable and real GDP as output variable for the MPI model. The results presented in Table 3.9 include knowledge economy growth considering education expenditure and secondary school enrolment as % of total as the input variable and computer users per 1000 of population as output variables in computing the MPI.

Table 3.8 Geometric means of MPI and its components (Cobb-Douglas), 2005-2010

DMU	effch	techch	pech	sech	tfpch
Indonesia	1.000	1.073	1.000	1.000	1.073
Malaysia	1.068	1.060	1.000	1.068	1.133
Philippines	1.084	1.059	1.000	1.084	1.148
Singapore	1.076	1.065	0.985	1.092	1.146
Thailand	1.037	1.057	1.046	0.991	1.096
South Korea	1.000	1.000	1.000	1.000	1.000
Mean	1.044	1.052	1.005	1.038	1.098

Note:
Effch – Technical efficiency change
Techch – Technological change
Pech – Pure Technical Efficiency Change
Sech – Scale efficiency change
Tfpch – Total Factor Productivity (TFP) change

If the changes in total factor productivity (TFPCH) index are greater than one (TFPCH > 1), this shows that there is an increase in TFP. If the TFPCH is lower than one (TFPCH < 1), it means that there is a decrease in TFP. There are two components of TFP; these are changes in technical efficiency (EFFCH) and changes in technology (TECHCH). If these two indexes are higher than one, it means that there are improvements in both technical efficiency and technology. If they are lower than one, it means that there are declines in both technical efficiency and technology.

We can divide the EFFCH index into two sub-indexes, known as changes in pure efficiency (PECH) and changes in scale efficiency (SECH). The SECH index shows the achievement of producing on an appropriate scale. Decomposition of the Malmquist TFP index is useful to determine the sources of the changes in TFP (Ramanathan, 2003).

As is evident from Table 3.8 (model with Cobb-Douglas components) the Philippines and Singapore exhibited an average positive increase in total factor productivity of 14.8% and 14.6% respectively over the sample period. For Philippines, this increase in TFP was composed of an 8.4% technical efficiency gain and a 5.9% gain due to technological progress. For this country, there has been no change in pure technical efficiency, thus meaning that the technical efficiency change was solely the product of scale efficiency expansion, which totalled 14.8%. A similar observation was recorded for Singapore, which also exhibited a productivity gain. On the contrary, Malaysia, Thailand and Indonesia recorded a lower value in the TFP compared to the Philippines and Singapore over the sample period. All countries exhibited a positive improvement in technical and technological efficiency. Indonesia, however, appeared to be the least successful country whereas South Korea showed no change in TFP of MPI. South Korea appeared to be the reference country, or in other words, the optimally efficient country in the production frontier. By allowing for constant returns to scale it can be shown that technical efficiency grew in most of the ASEAN countries.

Table 3.9: Geometric means of MPI and its components (Knowledge economy), 2005-2010

DMU	effch	techch	pech	sech	tfpch
Indonesia	1.055	1.042	1.000	1.055	1.099
Malaysia	1.025	1.063	1.000	1.025	1.089
Philippines	1.066	1.063	1.000	1.066	1.133
Singapore	1.000	1.052	1.000	1.000	1.052
Thailand	1.069	1.063	1.099	0.973	1.136
South Korea	0.999	1.061	0.998	1.001	1.060
Mean	**1.035**	**1.057**	**1.015**	**1.019**	**1.094**

Note:
Effch – Technical efficiency change
Techch – Technological change
Pech – Pure Technical Efficiency Change
Sech – Scale efficiency change
Tfpch – Total Factor Productivity (TFP) change

We can see from Table 3.9 (model with knowledge economy components) that the annual average value of EFFCH index was 1.035. This means that there was a general improvement in technical efficiency. However, there was no decrease in the components of EFFCH. The TECHCH index increased by 5.7%. The increase in TECHCH resulted in the increase in TFP. This implies that ICT and human capital have improved in all south-east Asian countries.

The value of EFFCH indexes which belong to Indonesia, Malaysia, the Philippines, and Thailand were higher than one. This means that these countries have a higher catching-up effect to reach the optimal production border/frontier. In other words, these countries have been successful in catching up the best production border which is determined by the reference country (Singapore). The most successful country for catch up is Thailand (6.9%). However, South Korea had EFFCH levels lower than 1, thus meaning that there is no catching-up effect in South Korea. In addition, Singapore has EFFCH indexes which are equal to 1. Singapore is the reference country, which means it is stable, with no success or failure in terms of catching up the best production border. In other words, Singapore's annual average technical efficiency level has not changed.

According to the technological change index (TECHCH), Malaysia, the Philippines and Thailand obtained the highest technological improvement during the period spanning 2005-2010. South Korea, Singapore and Indonesia followed these countries respectively. During this period all countries had the technological improvement, with the annual average TECHCH index measured at 1.057 and TFPCH index measured at 1.094 for all countries. The TECHCH index was higher than 1, thus meaning that the annual average of best production border is shifted up by technological improvement. When we look at the TFP of countries, we can see that Thailand and the Philippines had the highest increase in annual average TFP respectively. This implies that both the countries have improved their ICT and human resources development significantly within the reference period. The next section presents the conclusion and policy implications.

3.5 Conclusion and policy implication

This section seeks to explore whether the growth in productivity in ASEAN is attributed to either technical efficiency change or technological change or both, as well as and how ASEAN countries stand in human capital and ICT development. To achieve the above-mentioned objective, we employ the non-parametric method to compute the Malmquist Total Factor Productivity (TFP) indexes for a sample of ASEAN countries, namely Malaysia, Indonesia, the Philippines, Thailand, Singapore and South Korea. The Philippines claimed the greatest progress in technical efficiency of 8.4%, followed by Singapore with increased efficiency of 7.6%. There was a positive technological change for all countries using Cobb-Douglas production function components. The highest total factor productivity increased in the Philippines and Singapore. South Korea became the best performer or reference country in technological improvement efficiency in the first model.

In the second model, education expenditure, secondary school enrolment and computer user per 1000 of population were variables used for knowledge economy growth. The results indicate that Thailand and the Philippines experienced significant improvements in knowledge TFP growth. Other countries exhibited positive improvement of the TFP, although these were lower than the Philippines in terms of knowledge dissemination.

There are two ways to improve the TFP of knowledge economy growth. Firstly, ASEAN countries can improve inefficiency by improving their technical efficiency while using knowledge input-output factors. In other words, through reallocation of resources, countries can reach an optimal level of output and become more competitive.

Secondly, If ASEAN can develop a sustainable technological advancement through innovation in the ICT sector, it will create a new frontier i.e. the frontier will shift due to a sustainable increase in the TFP of the ICT sector. This will in turn lead to a sustainable increase in competitiveness. Identifying inefficient countries with respect to ICT and human resources adoption provides a benchmark, using which it is possible to enhance the cooperation between the ASEAN member countries. Human capital and ICT are considered the fuel driving the knowledge economy. ASEAN can improve and catch up the frontier countries in the world through the combination of these two knowledge economy factors. We believe the discussion and method presented in this section will contribute to the existing literature on productivity analysis. Chapters 4 and 5 will investigate the variation of efficiency and scale economics of knowledge input-output indicators of these countries.

Note 1: Functional definition of DEA MPI as follows:

$$M^{t+1}(x^{t+1},y^{t+1},x^t,y^t) = \left[\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)} \right]^{1/2}$$

where D^t is a distance function measuring the efficiency of conversion of inputs x^t to outputs y^t in the period t. As we know, DEA efficiency is considered a distance measure in the literature as it reflects the efficiency of input output conversion of

DMUs. In fact, should the following year see a change in technology which is (t+1), then,

$D^{t+1}(x^t, y^t)$ = efficiency of altering input in period t to output in period t ≠ $D^t(x^t, y^t)$.

Hence, we can technically say that Malmquist Productivity Index(MPI) is a geometric average of the efficiency and technological changes in the two referenced periods and thus it can be written as:

$$M^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\right]\left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}\frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{1/2}$$

M = ET

where E is the technical efficiency change and T is the technology change. E measures the change in the CRS technical efficiency of period t+1 over that in t. If E is greater than 1, we assume there is an increase in the technical efficiency. However, T represents the average technological change over the two referred periods.

See more discussion on advantages of the MPI method in productivity analysis in Appendix A (Table A.3).

[1] The Cobb-Douglas production function can be expressed as $\mathbf{Y = A * L^a * K^{(1-a)}}$
where: Y is real output
A is a scalar (measure of change due to technological improvement)
L is a measure of the flow of labour input
K is a measure of the flow of capital input
"a" is a fractional exponent, $0 < a < 1$, representing labour's share of output

CHAPTER 4: EVALUATING THE COMPARATIVE PERFORMANCE OF TECHNICAL AND SCALE EFFICIENCIES IN KNOWLEDGE-BASED ECONOMIES (KBES): A DATA ENVELOPMENT (DEA) CROSS-SECTION AND TIME SERIES ANALYSIS

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And

Afzal, M. N. I., & Lawrey, R. (2012c). A measurement framework for Knowledge-Based Economy (KBE) efficiency in ASEAN: A Data Envelopment (DEA) window approach. *International Journal of Business and Management*, *7*(18), 58-68.

4.0 Introduction

The use of the DEA method in cross-country studies is not yet widely applied, and is particularly lacking at state or country knowledge economy assessment levels (Tan et al., 2008)**.** DEA involves the application of the linear programming technique to trace the efficiency frontier. It was originally developed to investigate the performance of various non-profit organisations, such as educational and medical institutions, which were not suitable for traditional performance measurement techniques like regression analysis due to the complex relations of multiple inputs and outputs, absence of price and non-comparable units. The principles of DEA date back to Farrel (1957). The recent series of discussions on this topic began with the article by Charnes, Cooper & Rhodes (1978). A good introduction to DEA is available in Norman & Stoker (1991). Moreover, Cooper, Seiford & Tone (2000) provided recent and comprehensive material on DEA (Ramanathan, 2003). Studies on cross-country and knowledge economy performance assessment which employ the DEA method are provided in Table 4.1.

Table 4.1: The DEA method in country's macroeconomic and KBEs studies

Authors	Data sets	Input and outputs used in DEA model	Key results
Golany & Thore (1997)	From Statistical department of 72 developed and developing countries, 1970-1985	**Inputs:** real investment as % GDP, real gov. consumption as % GDP, education expenditure as % GDP **Outputs:** real GDP growth, infant mortality, enrolment ratio for secondary schools, welfare payments.	Japan, USA, Canada, Asian tigers show increasing returns to scale (IRS), Scandinavian and very poor developing countries show decreasing returns to scale (DRS).
Stanickova & Skokan (2012)	EUROSTATS, OECD data base	DEA on 27 Euro countries. Inputs: R&D expenditure as % GDP, employment rate, real investment as % GDP. Outputs: Real GDP (PPS) and Labour	Bulgaria, Romania, Italy, Greece Lithuania show DRS while Luxembourg, Malta and Cyprus show IRS.
Roman, M.	2003 and 2005,	Inputs: R&D expenditure, total	Both the countries show DRS

(2010)	EUROSTAT, National Institute for Statistics of Romania and Bulgaria	researchers, Outputs: patents, scientific & technical articles, high-tech exports as % of total	in knowledge production, Bulgaria is slightly better than Romania.
Hsu, Luo & Chao (2005)	WCY-2004	WCY-2004 pillars used as inputs and output variables for OECD & non-OECD countries.	Indonesia and Argentina outperform in all efficiencies scores and Turkey, Poland and Mexico appear stable efficiencies.
Abdelfattah, Ablanedo-Rosas & Gemoets (2011)	WDI-2005 data set for 54 developing countries	Only output variables from MDG programme	29 countries show as efficient
Ramanathan (2006)	Selected Middle east & North African countries, WDI-1999	Inputs and Outputs: ratio of labour to population, life expectancy, primary education teachers, GNP per capita, literacy rate, Mortality rate etc	Bahrain, Jordan, Kuwait and UAE are most efficient while Yemen is the least efficient country.
Christopoulos (2007)	Selected OECD & Non- OECD countries	Human capital, openness, are input variables while real GDP is the output variable	Movements towards openness increase the efficiency performance of the non-OECD countries
Mohamad (2007)	Selected Asia-Pacific countries. Data sets collected 1996, 2000, 2003	Inputs: Gov. expenditure as % GDP, Output: real GDP growth, the real employment rate, inflation rate	Only 7 of 25 selected countries are efficient
Tan, Hooy, Islam & Manzoni (2008)	2001	Inputs: R&D expenditure, labour productivity, average schooling. Output: mobile phone users, internet users, PC penetration, hi-tech exports	India, Indonesia, Thailand and China are inefficient countries due to outflow of human resources.

In summary, these empirical studies using the DEA method reveal that research and development (R&D) expenditure, foreign direct investment inflows (FDI), trade openness and education expenditure can be considered as input variables, while real GDP growth, high-tech exports as a percentage of total manufacturing exports, computer users, patents, and scientific and technical journal articles are commonly considered as output variables for assessing the performance of a country’s macro as well as knowledge economy.

4.1 Research framework

The reference period is determined by the start of the KBE framework concept by the OECD in 1995-1996 and ends at the availability of selected indicators at the national level in 2010. Accordingly, we use 1995 and 2010 as the two years for cross-section analysis in order to measure the efficiencies of the selected south-east Asian countries, namely Indonesia, Malaysia, the Philippines, Thailand and Singapore in all KBE dimensions. Data are collected from WCY-2011, WDI-2011 and ASEAN statistical yearbooks. Before describing the DEA methodology, we first formulated our policy-focussed KBE framework, with relevant input and output variables, in order to apply the DEA method. We built a policy-focussed KBE framework based on the OECD (1996) KBE definition considering four knowledge dimensions under which there are four output variables and various selected input variables in previous chapters. The output variables are real GDP growth for knowledge acquisition, scientific and technical journal articles per 1000 of population for knowledge production, computer users per 1000 of population for knowledge distribution and high-technology exports as % of total manufacturing exports for knowledge utilisation.

The KBE input-output variables were selected from OECD, WBI and APEC KBE frameworks by observing time series data availability, literature surveys and the requirement that data preferably be available for all the study countries for the two reference years for the purposes of comparison (ABS, 2002; Afzal & Lawrey, 2012a). This study applies the DEA approach by using the policy-focussed KBE framework for ASEAN-5.

4.1.1 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a methodology based upon an application of linear programming. It was originally developed for performance measurement. It has been successfully employed for assessing the relative performance or technical efficiency of a set of firms which use a variety of identical inputs to produce a variety of identical outputs. DEA is a non-parametric approach which calculates efficiency levels by carrying out linear programming for each unit in the sample. It measures the efficiency of the decision making units (DMU) by comparison with the best producer in the sample to derive compared efficiency. A distinctive feature of the DEA approach is that, for each DMU (e.g. an individual country), it calculates a single relative ratio by comparing total weighted outputs to total weighted inputs for each unit without requiring the proposition of any specific functional form.

According to the original Charnes, Cooper & Rhodes (CCR) (1978) model, the DEA efficiency value has an upper bound of 1 and a lower bound of 0. Two types of DEA models, namely the input-oriented and the output-oriented models, have been widely articulated by operational researchers. Though the input-oriented model focusses on cost minimisation while the output-oriented model focuses on output maximisation, evidence indicates that research results are not sensitive to which of the models is being used (Hsu, Luo & Chao, 2005). In the application of DEA, a linear programming model must be formulated and solved for each DMU. Such a requirement makes the calculation of efficiency scores for all of the studied countries a tedious job, although now through the use of software such as IDEAS, DEA-Solver, DEAP and EMS, analysts can estimate the efficiency scores for all DMUs in one DEA model, thus eliminating any potential human error. In addition to countries, DMUs can include manufacturing units, departments of big organisations such as universities, schools, bank branches, hospitals, power plants, police stations, tax offices, prisons, and defence bases, a set of firms or even practising individuals such as medical practitioners. This method has also recently been applied to measure efficiencies of knowledge economies (Tan et al., 2008).

4.1.2 Theoretical construction of DEA system

As we have seen, DEA is based on Technical Efficiency (TE) or performance efficiency, which can be shown as:

$$\text{Technical efficiency (TE)} = \frac{\sum WO}{\sum WI}$$

WO= weighted output, WI= weighted input

Mathematically, we can express the above relation by the following formula:

$$E_k = \frac{\sum_{j=1}^{M} U_j O_{jk}}{\sum_{i=1}^{N} V_i I_{ik}}$$

E_k = TE for the DMU_k (between 0 and 1)
K = Number of DMU_k, in the sample
N=Number of inputs used (i= 1, L, *N*)
M= Number of outputs (j= 1, L, *M)*
O_{jk} = The observed level of output j from DMU_k
I_{ik} = The observed level of input i from DMU_k
V_i = The weight of input i
U_j = The weight of output j

To measure TE_k for DMU_k by using linear programming the following problem must be solved;

Max TE_k, Subject to $E_k \leq 1$, k= 1,2, L, K

where TE_k is either maximising outputs from given inputs or minimising inputs for a given level of outputs. The above problem, as stated, cannot be solved because of difficulties associated with nonlinear (fractional) mathematical programming. Charnes, Cooper & Rhodes (1978) have developed a mathematical transformation called the CCR (the initials of their names) model which converts the above nonlinear programming to a linear one under constant returns to scale (CRS).

Modified linear programming is expressed by the following formula:

$$\text{Max} \sum_{j=1}^{M} U_j O_{jk}$$

S.t.

$$\sum_{i=1}^{N} V_i I_{ik} = 1$$

$$\sum_{j=1}^{M} U_j O_{jk} \leq \sum_{i=1}^{N} V_i I_{ik}$$

U_j , $V_i \geq \varepsilon > 0$
$\varepsilon > 0$

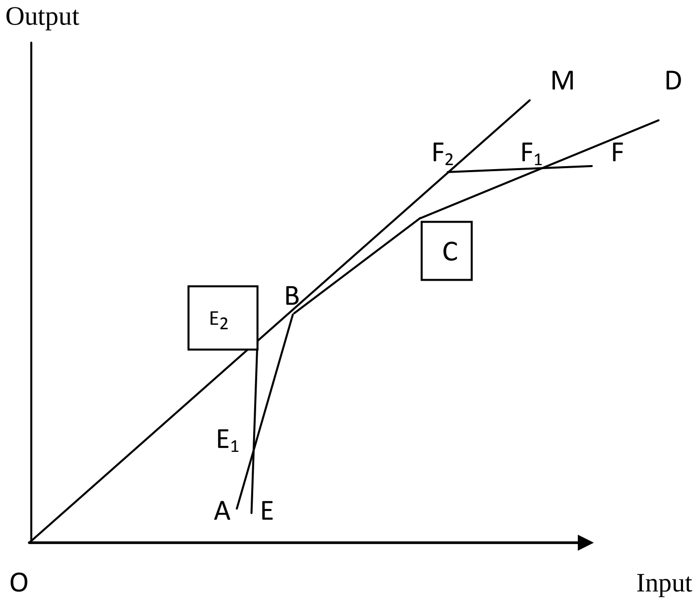
The above procedure can also be done by using input weights V_i and variable I_{ik} in place of U_j O_{jk} and subject to an output constraint under CRS. As a whole, the optimisation procedure in DEA ensures that the particular DMU being evaluated, in our study the countries, is given the highest score possible by maximising its relative efficiency ratio, whilst at the same time maintaining equity for all other DMUs. DEA establishes relative efficiency scores led by the benchmark of unity (1 or 100%) as the highest score possible for one or more DMU. For all DMUs (countries) there are two efficiency scores, namely overall technical and scale efficiencies (TSE) and scale efficiency (SE). TSE refers to the extent to which countries achieve the overall productivity attainable in the most efficient manner (Banker, Charnes & Cooper, 1984). TSE can be further decomposed into pure technical efficiency (PTE) and scale efficiency (SE). PTE refers to how efficiently countries transform their inputs into outputs. Scale efficiency, on the other hand, represents the extent of the scale's productivity or size of the operation. Increasing returns to scale exist when a proportional increase in all inputs causes outputs to increase by a greater proportion. Decreasing returns to scale happen when a proportional increase in all inputs causes output to increase by a smaller proportion. It is the ratio of TSE from the original CCR model to PTE obtained from the variable returns to scale BCC model. The scale efficiencies of a DMU reveal whether a DMU is performing increasing (IRS), decreasing (DRS) or constant returns to scale (CRS). The scale efficiency of a DMU operating in its most productive size is thus 1.

Banker, Charnes & Cooper (1984) developed the concept of variable returns to scale (VRS) by examining the sum of weights which are determined in the CCR (Charnes, Cooper & Rhodes) model. They added a modification to the original CCR model by arguing that if the sum of weights of inputs and outputs in the CCR model add up to more than 1, the scale size of the DMU is DRS. To achieve CRS or optimum productive size, a DMU should reduce the excess use of inputs. However, if the sum of weights adds up to less than 1, a DMU is said to have IRS. To achieve the most productive size i.e. 1, this DMU should expand or increase the use of productive resources. This modification to get the returns to scale in DEA is known as the BCC model, and is named after Banker, Charnes & Cooper.

Here,

CCR = Charnes, Cooper and Rhodes original model
CRS= Constant Returns to Scale
BCC= Banker, Charnes and Cooper model
VRS= Variable Returns to Scale
IRS= Increasing Returns to Scale
DRS= Decreasing Returns to Scale
TSE = Technical and Scale Efficiencies
PTE= Pure Technical Efficiencies
SE=Scale Efficiencies
MPSS = Most Productive Scale Size

Figure 4.1: CRS and VRS efficiency illustrated



As shown in Figure 4.1, we can explain scale efficiencies by considering the case of a single input and a single output. There are 6 DMUs, namely A, B, C, D, E and F. The piecewise linear frontier A-B-C-D is the BCC model (Banker, Charnes & Cooper) which follows the VRS assumption. Here in Figure 1, the VRS frontier shows that the four observations A, B, C and D are pure, technical, and efficient (PTE). However, an observation like E is inefficient and according to the BCC model, in contrast with the CCR model, the best practice for E is the projection E_1 on AB. Similarly, point F_1 can be obtained as a convex combination of the corner points C and D.

The CCR model satisfies the following 'ray property': if (X, Y) is a feasible production point, then (kX, kY) is also a feasible point, where k is a non-negative scalar. The ray O-B-M is the CCR frontier i.e. constant returns to scale where the optimum efficiency score is 1. Observation B is CCR-efficient. All other observations are CCR inefficient which means they are not following the CRS assumption. The best CCR practice for F is the projection F_2 on O-B-M. Therefore, the CCR frontier exhibits CRS while the BCC frontier exhibits IRS along A-B and DRS along B-C-D. In sum, we can state that the CCR model (without the convexity constraint) estimates the gross efficiency of a DMU i.e. TSE. This efficiency comprises technical efficiency and scale efficiency.

Technical efficiency describes the efficiency in converting inputs to outputs, while scale efficiency recognises that economy of scale cannot be attained at all scales of production, and that there is one most productive scale size, where the scale efficiency is maximum at 100% (Ramanathan, 2003; Bilal, Ahmed, Ahmed & Akbar, 2011). One can argue that a DMU can show an optimum technical efficiency (100% efficient) while operating in inefficient scale size. A firm or country may be technically efficient but may still be able to improve its productivity by exploiting scale economics. Indeed, this is what we illustrate in our research results by showing TSE, PTE and their scale size efficiencies. The DEA method does not require an explicit a priori determination of a production function i.e. there is no need to define a functional relationship between inputs and outputs, and it does not require information on prices. Therefore, DEA is suitable for measuring the efficiency of our study countries in this research.

4.1.3 Model specification

The fundamental DEA models can be grouped as (1) the models for DMUs with constant returns to scale (CRS) under CCR formulations or the models for DMUs with variable return to scale (VRS) under BCC formulations and (2) input-oriented models or output-oriented models. To select the exact model, one must answer the following series of questions (Ramanathan, 2003):

1. Are the DMUs within the data set experiencing CRS or VRS?
2. Are the policy makers more flexible and interested in changing (increasing/maximising) the outputs of the DMUs or changing (reducing/minimising) the inputs of the DMUs?

The answer to the first question is found by considering both CRS and VRS efficiency scores because the variables are not conventional factors of production. It may exhibit CRS, IRS or DRS. when answering the second question, we consider an output oriented model because in our study we want to establish whether or not governments wish to maximise/increase output from given inputs in various KBE dimensions.

4.2 Results and discussions

DEA analyses of the data as presented in Tables 4.2 to 4.9 were conducted using DEAP (Data Envelopment Analysis Programme) software, Version 2.1 developed by Tim Coelli in 1996. Note that listed efficiencies should be viewed as relative to the best performing country in the particular year and particular KBE dimension. Based on the rule of thumb of DEA, the number of DMUs should be greater than double the sum of inputs and outputs. Therefore, we added South Korea, a member of ASEAN and an additional three countries to make robust results for the analysis. The results follow the sequence of our policy focussed KBE framework.

Table 4.2: Efficiency scores of selected south-east Asian countries for the Knowledge Acquisition Dimension in 1995

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.744	0.914	0.814	DRS
Malaysia	0.266	1.000	0.266	DRS
Philippines	0.224	0.507	0.443	DRS
Singapore	0.122	0.816	0.150	DRS
Thailand	0.392	1.000	0.392	DRS
South Korea	1.000	1.000	1.000	CRS

Table 4.3: Efficiency scores of selected south-east Asian countries for the Knowledge Acquisition Dimension in 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	1.000	1.000	1.000	CRS
Malaysia	0.432	0.817	0.528	DRS
Philippines	0.991	1.000	0.991	DRS
Singapore	0.389	1.000	0.389	DRS
Thailand	0.691	0.986	0.701	DRS
South Korea	1.000	1.000	1.000	CRS

The first result of the DEA calculations is an efficiency rating of each observation (here, country). A rating of 100% (or 1.000) indicates that the country is located on the efficiency frontier. An efficiency rating less than 1.000 signals a non-optimal situation. A second set of calculations provides a measure of the returns to scale of each country. Theoretically, constant returns to scale (CRS) are said to exist at a point on the frontier if an increase of all inputs by 1% leads to an increase of all outputs by 1%. Decreasing returns to scale (DRS) are said to prevail if outputs increase by less than 1%, while increasing returns to scale (IRS) are present if they increase by more than 1%. Generally speaking, a DRS situation is associated with a mature economy where basic economic and social needs have already been met, so that the incremental return of additional efforts is falling. In contrast with DRS, IRS would seem to be associated with high productivity of factors of production where a nation can enjoy increasing incremental returns on economic efforts (Golany & Thore, 1997).

Our calculations of returns to scale have a direct interpretation in terms of KBE policy. It is clear that a country with DRS in any KBE dimension is not using its KBE inputs optimally, while a country with IRS can be expected to be engaged in rapid economic growth and higher KBE outputs. Both DRS and IRS are considered as inefficient scale sizes. The most optimal use of KBE resources is operating at CRS or scale size 1.

Tables 4.2 and 4.3 show the results in the knowledge acquisition dimension where South Korea had the highest efficiency score and has most productive scale size in both the years. It indicates that South Korea is using its knowledge acquiring inputs - trade openness and FDI - most efficiently compared to other sample countries.

However, from our analysis, it appears that all other countries in both years were experiencing DRS, thus implying inefficient use of their resources, with the exception of Indonesia in 2010. Indonesia improved its efficiency in 2010 compared to 1995. This DRS inefficiency for other member countries means that it would be possible for these countries to reduce the use of its inputs while still obtaining the same amounts or more of the outputs in the knowledge acquisition dimension.

Table 4.4: Efficiency scores of selected south-east Asian countries for Knowledge Production Dimension in year 1995

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.508	1.000	0.508	IRS
Malaysia	0.635	0.674	0.942	DRS
Philippines	0.478	1.000	0.478	IRS
Singapore	0.622	0.653	0.952	DRS
Thailand	1.000	1.000	1.000	CRS
South Korea	1.000	1.000	1.000	CRS

Table 4.5: Efficiency scores of selected south-east Asian countries for Knowledge Production Dimension in year 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.330	1.000	0.330	IRS
Malaysia	0.314	0.387	0.811	DRS
Philippines	0.216	1.000	0.216	IRS
Singapore	1.000	1.000	1.000	CRS
Thailand	1.000	1.000	1.000	CRS
South Korea	0.706	0.757	0.934	IRS

Tables 4.4 and 4.5 show the efficiency score of the knowledge production dimension. Indeed, Thailand and South Korea in 1995 and Singapore and Thailand in 2010 were the best performers, with the most productive scale size and 100% efficiency. However, Indonesia and the Philippines in both years, and South Korea in 2010 were showing increasing returns to scale (IRS). The presence of IRS implies that these countries are enjoying higher outputs in terms of producing innovation and new ideas using their KBE inputs of R&D expenditure and IPR due to their highly productive factors of production. This situation may spur the governments of said countries to invest more in R&D, which will be seen as a sound investment in a productive workforce and in human capital.

Table 4.6: Efficiency scores of selected south-east Asian countries for Knowledge Distribution Dimension in year 1995

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.054	1.000	0.054	IRS
Malaysia	0.310	0.509	0.609	IRS
Philippines	0.039	0.039	1.000	CRS
Singapore	1.000	1.000	1.000	CRS
Thailand	0.124	1.000	0.124	IRS
South Korea	0.316	0.372	0.851	DRS

Table 4.7: Efficiency scores of selected south-east Asian countries for Knowledge Distribution Dimension in year 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.111	1.000	0.111	IRS
Malaysia	0.556	1.000	0.556	IRS
Philippines	0.151	1.000	0.151	IRS
Singapore	1.000	1.000	1.000	CRS
Thailand	0.197	0.376	0.523	IRS
South Korea	0.965	0.966	0.999	DRS

According to Tables 4.6 and 4.7, Indonesia, Malaysia, the Philippines and Thailand all exhibited IRS in 2010, thus implying that they can enjoy multiplying advantages in the use of ICT with their current education expenditure and school enrolments. This can be seen as intuitively obvious. The more the government invests in education and increases the school enrolment ratio, the faster it will get the highest number of computer and ICT users per 1000 of population under IRS. The increasing rate of ICT users will lead the the increased effectiveness and efficiency of knowledge distribution in the respective economies in the long run. The Philippines showed IRS in 2010, although it was efficient in 1995. However, South Korea showed DRS in our analysis, thus implying that South Korea is yet to get the optimum use of its education expenditure and school enrolment.

The most interesting finding from our analysis is that Singapore exhibits the most productive scale size in both years. That is, it is the best performer in the knowledge distribution dimension. Singapore sets an example for other ASEANs as well as developing countries by overcoming its size and natural resource constraints by leveraging on the region and the world. It is a manufacturing base which produces, with increasing intensity, technology and knowledge-intensive goods. It has also experienced a recent increase in the number of ICT users (Yue & Lim, 2003). In 2010, its computer users numbered 827.48 per 1000 of the population, which led to its number 1 ranking in ASEAN (WDI-2011). Our calculation also finds Singapore to be the most efficient country in this dimension for both the years.

Table 4.8: Efficiency scores of selected south-east Asian countries for Knowledge Utilisation Dimension in year 1995

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.176	0.193	0.913	DRS
Malaysia	1.000	1.000	1.000	CRS
Philippines	1.000	1.000	1.000	CRS
Singapore	0.719	1.000	0.719	DRS
Thailand	0.669	0.770	0.868	DRS
South Korea	1.000	1.000	1.000	CRS

Table 4.9: Efficiency scores of selected south-east Asian countries for Knowledge Utilisation Dimension in year 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.205	1.000	0.205	IRS
Malaysia	0.425	0.733	0.580	DRS
Philippines	1.000	1.000	1.000	CRS
Singapore	0.437	0.762	0.573	DRS
Thailand	0.365	0.414	0.882	DRS
South Korea	1.000	1.000	1.000	CRS

Finally, Tables 4.8 and 4.9 show the results of the knowledge utilisation dimension where Malaysia, the Philippines and South Korea in 1995 and the Philippines and South Korea in 2010 were the most productive countries. However, all countries exhibited DRS, with the exception of Indonesia, which exhibited IRS in 2010. The interesting point from this calculation is the consistent best performance by the Philippines and South Korea in this dimension. We used FDI inflows as a percentage of GDP and the knowledge transfer rate from universities to industry (WCY-2011 executive survey based on an index from 0 to 10) as input variables and high-tech exports as % of total manufacturing exports as the output variable for this dimension.

If we explain this in terms of recent phenomena, we find that the Philippines had the largest share of high-tech products in manufactured exports in 2010. Its % of high-tech products as a % of total manufacturing exports was 65.65%, followed by Singapore with 50.01%, Malaysia with 48.11%, Indonesia with 13.13% and Thailand with 27.12% in the same year (WDI-2011). This implies that the Philippines is making optimum use of its FDI inflows in order to produce new knowledge and ideas in the universities which eventually transfer this knowledge to high-tech industrial growth.

Theoretically, investing in the knowledge intensive sectors such as ICT, high-tech goods, bio-technology etc. can increase the productive capacity of the other production factors as well as transforming them into new products and processes which leads a country to be more efficient in KBE (Afzal & Lawrey, 2012b; Lee, 2001). Hence, we can say that the other inefficient countries can emulate the best performing country in order to achieve optimum efficiency.

4.3 Conclusion

The results of our analysis have interesting policy implications for promoting sustainable, knowledge-based economic growth in the south-east Asian region. We wish to stress here that the findings of the study are critically based on the choice of KBE variables, and hence, the policy implications discussed here should be considered within this perspective. In this chapter we review our policy-focussed KBE framework and apply the DEA cross-section method to show the technical and scale efficiency of the selected south-east Asian countries in each KBE dimension. We use mostly WDI and WCY data sources to give the current state of performance of these countries.

The results show that Indonesia in the knowledge acquisition dimension, Singapore, South Korea and Thailand in the knowledge production dimension, Singapore in the knowledge distribution dimension and the Philippines and South Korea in the knowledge utilisation dimension were the most productive and 100% efficient countries in one referred year or the other. In the case of decreasing returns to scale (DRS) inefficiency, governments should use their existing resources more efficiently, while with increasing returns to scale inefficiency (IRS), governments can enjoy increasing marginal returns from KBE outputs until they reach the optimum level. This indicative analysis shows that countries exhibiting DRS or IRS have efficiency gains to be made compared to countries exhibiting CRS.

The above results raise the interesting issue for future research of how future policy can aid the promotion of these available efficiency gains. Finally, we believe that the discussion and method presented in this chapter will contribute to future KBE policy formulation, not only in ASEAN but also in other emerging economies.

4.4 Data Envelopment (DEA) Window Approach for measuring time Series KBE efficiency in selected south-east Asian countries

4.4.1 DEA/Window Analysis Methodology

Basic conditions which are important when using DEA are as follows:

1. Positive values: generally, the DEA formulation requires that the input and output variables be positive (greater than zero).
2. Isotinicity: it is essential that the functions relating inputs to outputs have a property called isotonicity, which means that an increase in any input results in some output increase and not a decrease in any output.
3. A general rule is that three DMUs are required for input and output variables used in the model in order to insure sufficient degrees of freedom for a meaningful analysis.
4. Homogeneity of DMUs: DEA requires a relatively homogenous set of entities. That is, all entities included in the evaluation set should have the same inputs and outputs in positive amounts.
5. Control of weights: The weights U_j and V_i are determined while solving the DEA model. These weights are computed in such that a way the organisation under evaluation is placed in the best possible light to the other units in the data set.

4.4.2 DEA/Window Analysis

Window Analysis was proposed formally by Charnes, Clark, Charles, Cooper, & Golany (1985) as a time dependent version of DEA analysis. In order to capture the variations of efficiency over time, Charnes et al. (1985) proposed this technique in his study. Window analysis generally assesses the performance of a DMU over time by treating it as a different entity in each period. This method makes it possible to track the performance of a unit or a process.

The basic idea is to look at each DMU as if it were a different unit in each of the reporting dates. Following this, each DMU is not necessarily compared with the whole data set, but instead only with alternative subsets of panel data. Most DEA analysis is handled on the basis of cross-sectional analysis, which usually evaluates DMU efficiency, a stationary factor. However, this seems to be a weak point of DEA analysis. To supplement this weak point, the DEA/window analysis approach was developed (Park et al. 2011). DEA/Window ideally follows the moving average concept where, given a series of numbers and a fixed subset size, the first element of the moving average is obtained by taking the average of the initial fixed subset of the number series. Following this, the subset is modified by "shifting forward", that is, excluding the first number of the series and including the next number following the original subset in the series. This creates a new subset of numbers, which is averaged. This process is repeated over the entire data series.

The DEA/Window approach considers trend, stability, and seasonal behaviour. In general, when the total period of data collected for DEA/Window analysis is ‘S’ and window range is ‘R’, then the number of windows are as follows, w= S-R+1 (Cooper et al., 2000). In our case we had 6 years (2005-2010) whilst window range was 3, thus meaning that we had 4 windows for each country in each knowledge dimension.

4.5 Empirical results and discussion

DEA/Window analysis can be conducted using a variety of different software. In this study we used Efficiency Measurement System (EMS) software, version 1.3 developed by Holger Scheel in 2000. This study assumed constant returns to scale; that is, as all inputs double, all outputs will double. The window analysis enabled us to identify the best and the worst performing countries in a relative sense. The overall efficiency for each DMU (country) was calculated by adopting the original CCR model prepared by Charnes, Cooper & Rhodes. Subsequently, the DEA/Window analysis was applied in order to find, over time, the trend and stability of efficiencies. Based on the rule of thumb of DEA, the number of DMUs should be greater than double the sum of inputs and outputs. Therefore, we added South Korea, a member of ASEAN as well as three additional countries, to make the analysis robust. In addition to the efficiency analysis we calculated mean, standard deviation and coefficient of variation for each window. The study countries were compared on the basis of average efficiency i.e. mean and coefficient of variation (C.V.). We used this C.V. technique for a comparison because the C.V. aims to describe the dispersion of the variable in a way which does not depend on the variable's measurement unit. Indeed, the standard formulation of the C.V. is usually the ratio of the standard deviation to the mean. The lower the C.V., the smaller the dispersion relative to the predicted mean value, which is suggestive of a better result in comparison with higher C.V values.

The results will follow the sequence of our policy-focussed KBE framework (Chapter 3) and all values are shown in percentage points i.e. the efficiency will vary from 0-100% according to the DEA condition.

Table 4.10: Knowledge Acquisition Dimension

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**Mean**	**S.D**	**C.V**
Indonesia	99.99	95.38	100				98.45	2.66	.027
Indonesia		95.38	100	94.19			96.52	3.06	.031
Indonesia			100	94.19	98.17		97.45	2.97	0.03
Indonesia				92.69	94.21	100	95.63	3.8	0.04
						Average =	**97.63**	**3.12**	**0.032**
Malaysia	31.99	31.87	34.16				32.67	1.2	0.039
Malaysia		31.87	34.16	27.68			31.23	3.2	0.105
Malaysia			34.21	27.83	14.25		25.43	10.19	0.40
Malaysia				26.71	12.07	43.17	27.31	15.55	0.56
						Average =	**29.16**	**7.5**	**0.27**
Philippines	54.18	53.78	82.99				63.65	16.75	0.26
Philippines		53.78	82.99	54.02			63.59	16.79	0.26
Philippines			83.13	54.65	16.07		51.28	33.65	0.65
Philippines				49.54	15.11	99.09	54.58	42.21	0.77
						Average =	**58.27**	**27.35**	**0.48**
Singapore	18.49	21.17	21.57				20.41	1.67	0.082
Singapore		21.17	21.57	4.39			15.71	9.80	0.62
Singapore			21.57	4.42	2.14		9.37	10.62	1.13
Singapore				4.12	2.14	38.93	15.06	20.69	1.37
						Average =	**15.13**	**10.69**	**0.80**
Thailand	33.18	36.48	36.64				35.43	1.95	0.055
Thailand		36.48	34.64	18			29.70	10.17	0.34
Thailand			34.64	18.05	22.12		24.93	8.62	0.34
Thailand				17.82	20.91	69.09	35.94	28.75	0.79
						Average =	**31.5**	**12.37**	**0.38**
Korea	73.01	100	100				91.0	15.58	0.171
Korea		100	100	40.97			80.32	34.08	0.42
Korea			100	41.53	5.83		49.12	47.54	0.96
Korea				35.31	5.11	100	46.80	48.47	1.03
						Average =	**66.81**	**36.41**	**0.64**

The first result of the DEA calculations, whether cross-section or window analysis, is an efficiency rating of each observation by country. A rating of 100% indicates that the country is located on the efficiency frontier. An efficiency rating less than 100% signals non-optimal behaviour. In our analysis, we showed efficiencies of the countries in each time period window. We were, however, interested to analyse the study countries on the basis of the average efficiency (mean) over multiple time-periods and their corresponding C.V. values in each KBE dimension.

The results for the knowledge acquisition dimension are shown in Table 4.10. Observing the average efficiency values from the table, Indonesia had the highest mean of 97.63% and lowest C.V value of 0.032 compared to the other 5 countries.

This indicates that Indonesia is the best performer in the knowledge acquisition dimension during the relevant time period. This can be explained in two different ways. First of all, the highest mean and lowest C.V values of Indonesia suggest that most of Indonesia's knowledge stock and flows depend on FDI and openness. The country is making good use of these two input factors in order to generate economic growth. On the other hand, it also implies that Indonesian domestic knowledge workers are not skilled enough to contribute to economic growth by using indigenous knowledge stock or flows. Researchers have found that a critical mass of human capital has not been achieved by Indonesia compared to other big ASEAN economies (Tjakraatmadja et al., 2011). Other countries in this region, and particularly Singapore, S. Korea, Malaysia and Thailand, are utilising their domestic knowledge workers to accelerate economic growth compared to Indonesia in this time period. Therefore, we can say that Indonesia is heavily dependent on foreign assistance in order to acquire knowledge and generate economic growth.

Table 4.11 shows the results of the knowledge production dimension. In this case, Thailand scored the highest mean value of 91.09% followed by South Korea with 70.87% and Singapore with 44.37%. In this dimension the present study considered R&D expenditure and the extent to which intellectual property rights are adequately enforced (WCY-2011, IMD WCY executive survey based on an index from 0 to 10) as input variables and scientific and technical journal articles per 1000 of the population as the output variable. However, According to World Development Indicators (WDI) 2010 data, Singapore R&D expenditure as a % of GDP was the highest at 3.21%, compared to Indonesia with 0.08%, Malaysia with 0.88%, the Philippines with 0.12% and Thailand with 0.24%. In addition to this, in 2010 Singapore produced 3901.6 original scientific articles compared to Indonesia's 200.1, Malaysia's 880, the Philippines' 197 and Thailand's 1827 (WDI-2010). The raw data indicated that Singapore is a better performer compared to other ASEAN countries, though our efficiency analysis showed that Thailand is the most efficient country. This is due to the weights which DEA/Window analysis takes into account for efficiency measurement. We can therefore can say there is a clear distinction between looking at the raw data and DEA/Window analysis to measure a country's performance. This is so with the case of Thailand.

Table 4.11: Knowledge Production Dimension

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**Mean**	**S.D**	**C.V**
Indonesia	49.88	43.58	30.01				41.15	10.15	0.24
Indonesia		43.58	30.01	34.73			36.10	6.8	0.19
Indonesia			30.01	34.73	34.57		33.10	2.6	0.08
Indonesia				36.53	36.37	32.09	34.99	2.51	0.07
						Average =	**36.33**	**5.51**	**0.14**
Malaysia	14.58	15.97	18.97				16.50	2.24	0.13
Malaysia		15.97	18.97	16.48			17.14	1.60	0.09
Malaysia			19.13	16.72	14.46		16.77	2.33	0.13
Malaysia				31.60	31.25	31	31.28	0.30	0.009
						Average =	**20.42**	**1.61**	**0.08**
Philippines	18.02	21.85	21.53				20.46	2.12	0.10
Philippines		21.85	21.53	23.77			22.38	1.21	0.05
Philippines			21.53	23.77	23.82		23.04	1.30	0.056
Philippines				25.01	25.06	20.99	23.68	2.33	0.098
						Average =	**22.39**	**1.74**	**0.07**
Singapore	26.40	28.21	25.62				26.74	1.32	0.04
Singapore		28.21	25.62	23.14			25.65	2.53	0.09
Singapore			26.32	23.79	27.54		25.88	1.91	0.07

Singapore				97.67	100	100	99.22	1.34	0.01
						Average =	**44.37**	**1.7**	**0.05**
Thailand	66	76.24	100				80.74	17.44	0.21
Thailand		76.24	100	95.06			90.43	12.53	0.13
Thailand			100	95.06	87.29		94.11	6.40	0.06
Thailand				100	97.26	100	99.08	1.58	0.01
						Average =	**91.09**	**9.48**	**0.1**
Korea	97.90	100	99.74				99.21	1.14	0.011
Korea		100	99.74	10.69			70.14	51.48	0.7
Korea			100	10.72	9.68		40.13	51.84	1.29
Korea				81.29	70.12	70.64	74.01	6.30	0.08
						Average =	**70.87**	**27.6**	**0.5**

Table 4.12 reveals the knowledge distribution dimension window results. Indeed, Singapore scored the highest mean of 95.86% and the lowest value of C.V, which is the best result compared to other ASEAN members. Here, we used education expenditure as a % of GDP and secondary school enrolment as a % of total enrolment as input variables whilst computer users per 1000 of the population was used as the output variable. Singapore had the highest number of computer users at 827.48 per thousand of the population compared to Indonesia with 42.51, Malaysia with 337, the Philippines with 81.12 and Thailand with 122.61 in 2010 (WDI-2010, WCY-2011). Moreover, Singapore's education expenditure as a percentage of GDP, and secondary school enrolment ratio were historically high in ASEAN (Heng et al., 2002).

This high performance of input–output KBE indicators leads to a number 1 ranking for Singapore in the knowledge distribution dimension. S. Korea was the second best performer in this dimension, with a 92.44% mean and 0.05 C.V value.

Table 4.12: Knowledge Distribution Dimension

	2005	2006	2007	2008	2009	2010	Mean	S.D	C.V
Indonesia	7.58	6.75	8.49				7.60	0.87	0.11
Indonesia		6.75	8.49	11.97			9.07	2.65	0.29
Indonesia			8.02	11.31	9.84		9.72	1.64	0.16
Indonesia				10.88	9.47	11.06	10.47	0.87	0.083
						Average =	**9.21**	**1.49**	**0.12**
Malaysia	45.11	49.52	55.22				49.95	5.06	0.10
Malaysia		46.30	51.62	56.04			51.32	4.87	0.09
Malaysia			46.04	49.97	53.54		49.85	3.75	0.07
Malaysia				48.29	51.73	55.62	51.88	3.66	0.07
						Average =	**50.75**	**4.3**	**0.08**
Philippines	10.11	11.83	13.53				11.82	1.71	0.14
Philippines		11.30	12.91	14.94			13.05	1.82	0.13
Philippines			11.25	12.79	13.99		12.67	1.37	0.10
Philippines				12.36	13.52	15.13	13.67	1.39	0.10
						Average =	**12.80**	**1.57**	**0.11**
Singapore	93.20	95.90	100				96.36	3.42	0.035
Singapore		93.38	100	100			97.79	3.82	0.035
Singapore			94.44	90.13	100		94.85	4.94	0.052
Singapore				86.76	96.63	100	94.46	6.88	0.07
						Average =	**95.86**	**4.76**	**0.04**
Thailand	12.89	16.97	18.07				15.97	2.7	0.17
Thailand		15.86	16.89	18.27			17.0	1.2	0.07
Thailand			15.07	16.29	18.31		16.55	1.6	0.09

Thailand				15.74	17.69	19.65	17.69	1.9	0.11
						Average =	**16.80**	**1.85**	**0.10**
Korea	88.95	94.45	100				94.46	5.5	0.05
Korea		89.01	95.14	100			94.71	5.5	0.05
Korea			83.37	89.18	94.90		89.15	5.7	0.06
Korea				86.17	91.70	96.48	91.45	5.15	0.05
						Average =	**92.44**	**5.46**	**0.05**

Finally, in Table 4.13 we present the results of the knowledge utilisation dimension.

Table 4.13: Knowledge Utilisation Dimension

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**Mean**	**S.D**	**C.V**
Indonesia	31.05	27.11	18.63				25.59	6.34	0.2
Indonesia		25.33	17.53	17.56			20.14	4.49	0.2
Indonesia			17.53	17.56	25.35		20.14	4.45	0.2
Indonesia				17.11	23.71	20.47	20.43	3.3	0.1
						Average =	**21.57**	**4.64**	**0.17**
Malaysia	75.22	56.06	52.47				61.25	12.23	0.19
Malaysia		56.06	52.47	44.09			50.87	6.14	0.12
Malaysia			52.47	44.09	73.88		56.81	15.36	0.27
Malaysia				42.97	73.88	42.50	53.11	17.98	0.33
						Average =	**55.51**	**12.92**	**0.2**
Philippines	100	90.12	100				96.70	5.7	0.05
Philippines		90.12	100	100			96.70	5.7	0.05
Philippines			100	100	95.78		98.59	2.4	0.02
Philippines				100	90.26	100	96.75	5.6	0.05
						Average =	**97.18**	**4.85**	**0.04**
Singapore	55.97	52.93	40.68				49.86	8.09	0.16
Singapore		52.93	40.68	45.21			46.27	6.19	0.13
Singapore			40.68	45.21	44.22		43.37	2.38	0.05
Singapore				44.06	43.10	43.67	43.61	0.48	0.01
						Average =	**45.77**	**4.2**	**0.06**
Thailand	39.35	38.37	45.01				40.91	3.58	0.08
Thailand		38.37	45.01	36.36			39.91	4.52	0.11
Thailand			45.01	36.36	38.47		39.94	4.51	0.11
Thailand				35.44	36.87	36.48	36.26	0.73	0.02
						Average =	**39.25**	**3.33**	**0.07**
Korea	72.23	95.67	100				89.3	14.9	0.16
Korea		81.74	100	89.73			90.49	9.15	0.10
Korea			100	84.93	100		94.97	8.7	0.09
Korea				84.93	100	97.11	94.01	7.9	0.08
						Average =	**92.19**	**10.16**	**0.10**

When looking at Table 4.13 it is clear that the Philippines had the highest mean of 97.18% and the lowest C.V value in the knowledge utilisation dimension. This indicated that the Philippines is the best performer in this dimension. We used FDI inflows as a percentage of GDP and knowledge transfer rate from university to industry (WCY-2011 executive survey based on an index from 0 to 10) as input variables whilst high-tech exports as a % of total manufacturing exports was used as the output variable. The Philippines is currently the largest exporter of semi-conductors in the world and Japan is the number one buyer of these high-tech products from the Philippines (Lall, 2000). South Korea is the next best performer, with average efficiency of 92.19% in the knowledge utilisation dimension. Information and communication products, electronic goods, pharmaceutical and bio-tech products are considered high-tech export goods in this region.

4.6 Conclusion and policy recommendations

The results of our analysis have interesting policy implications for the promotion of KBE in selected south-east Asian countries. We wish to stress here that the findings of the study are critically based on the choice of KBE variables, and hence, the policy implications discussed here should be considered within this perspective. This section of Chapter 4 analyses the performance efficiencies in four knowledge dimensions of the selected south-east Asian countries for the period spanning 2005-2010. The study has indicated how the use of DEA/Window analysis can identify how individual countries' performance varies in different knowledge dimensions over time. This approach is advocated over the commonly used cross-sectional DEA analysis. Observing the average efficiency (mean) and the coefficient of variation values (C.V.) of DEA/Window analysis in four knowledge dimensions, firstly, we found that Indonesia had the highest mean of 97.63% and lowest C.V. value of 0.032 compared to other ASEAN members in the knowledge acquisition dimension. This implies that Indonesia is the best performer in this dimension, using FDI inflows and trade openness to generate high economic growth, but with underutilised domestic knowledge stocks and flows. In the case of knowledge production and distribution, our results showed that Thailand and Singapore were the best performers respectively compared to other ASEAN countries. This implies that the highly productive domestic knowledge workers of Thailand and Singapore are making best use of their R&D expenditure to produce new ideas, knowledge and innovations.

In terms of knowledge utilisation, the Philippines was the best performer compared to other sample countries. In fact, the Philippines scored the highest mean efficiency with 97.18% and the lowest C.V. value of 0.04 in the sample from our analysis. The reason behind this success of the Philippines is its deep pool of skilled human resources. The Philippines had a 94% literacy rate and a large pool of college students. It also showed good English proficiency, ranking as the third largest English speaking nation in the world. In Asia, the country's supply of IT workers was second only to that of India, which has a population of over one billion. The findings of this study suggest that in order to become a successful KBE, Indonesia should invest more in knowledge production, distribution and utilisation. Singapore should consider the knowledge utilisation dimension as a future investment sector. The Philippines' prime focus should be on how to make more use of the knowledge acquisition, production and distribution dimensions in order to sustain their advances in knowledge utilisation. Finally, a balanced development in all four knowledge dimensions for Malaysia, South Korea and Thailand is required if they are to become efficient performers in KBE.

This research, while evaluating the relative efficiency scores using DEA/Window analysis, did not restrict any input or output weights. This may affect the results if certain input or output measures are more important than others. In future research, it may be interesting to identify such weights to reflect relative importance and integrate them into the analysis. The next chapter will investigate two case studies using the DEA model to demonstrate the concept of most productive scale size and how to find peer DMUs for inefficient units. Moreover, the next chapter will critically evaluate the pros and cons of World Bank Knowledge Assessment Methodology (KAM).

CHAPTER 5: TWO CASE STUDIES ON R&D EFFICIENCY AND WORLD BANK KNOWLEDGE ASSESSMENT METHODOLOGY (KAM)

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And

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5.0 Case study 1 - R & D efficiency

The blueprint of a knowledge economy is the spirit to endogenous growth models in which new ideas are the main driver of long-run growth (Cullmann, Schmidt-Ehmcke & Zloczysti, 2009). The empirical literature accepts the importance of the level and dynamics of public R&D expenditures behind new innovation and economic growth in any economic systems (OECD, 1996). Therefore, the efficient usage of the government R&D expenditure becomes increasingly important in a globalised world. Countries are facing high levels of competition in domestic and foreign markets for innovative products (or high-tech goods) and future technology. This encourages nations to constantly update their technological potential and efficiencies. With this in mind, the main stream economic theories have emphasised that R&D, innovation, and human capital are the predominant determinants of growth in a knowledge-based economy (Afzal & Siddiqui, 2011).

Therefore, the motivation of our research comes under circumstances where we argue that to prevent decreasing returns and scale inefficiency in output, we need efficient government R&D expenditure in order to promote innovation. Otherwise, this scale inefficiency will upset the economic growth potential. To fulfil our objective, we used a non-parametric mathematical method called Data Envelopment Analysis (DEA) to measure the efficiency and demonstrate the most productive scale size, peer countries in detail.

In this chapter we illustrate the concept and process used to find the most productive scale size for the inefficient DMUs. In the previous chapter DEA analysis showed the scale efficiency, and time series variation of efficiency score using CRS and VRS model. In the previous chapter, we have not addressed the issue of peer DMUs for inefficient countries or the question regarding which DMUs emulate. With the help of two case studies, the present research addresses this issue; an issue which makes a significant contribution to DEA analysis.

5.1 Literature review

There are several KBE methodologies and frameworks which have been developed by different organisations to measure determinants of sustainable R&D growth in KBE. Among them this study considered OECD and WBI frameworks in order to analyse the importance of public R&D expenditure, innovation and economic growth in KBE. The OECD published a report on the knowledge-based Economy in 1996 (OECD, 1996) in which they proposed statistical indicators on the KBEs. It published another set of reports in 1999 and started producing results from the two-year Growth Project in 2000. The thrust for the project was to discover the causes of different economic growth of member nations during the 1990s. According to the framework, the root of KBE was formulated by the famous economists Romer (1986) and Helpman & Grossman (1991) who developed new growth theories to explain the forces which drive long-term economic growth.

According to the neo-classical production function, diminishing returns occurs as more capital is added to the economy and capital stops growing when investment is equal to depreciation, although this may be offset by the flow of new technology. According to new growth theory, knowledge is capable of lifting the returns on investment, which can in turn increase the stock of knowledge in society. Thus, in order to create new ideas in society, the government uses public R&D expenditure to support innovation culture in the country.

Innovation through efficient public R&D expenditure can spill over from one firm or industry to another, with little extra cost incurred. Such spill-over can ease the constraints on scarcity of capital and prolong long term economic growth. OECD therefore places emphasis on i) expenditures on research and development (R&D); ii) employment of engineers and technical personnel; iii) patents; and iv) international balances of payments for technology for long run sustainable growth.

The World Bank Institute (WBI) (1999) has developed a KBE framework for its member states in order to define their level of economic development and how to achieve sustainable economic growth in KBEs. It has been found that the successful transition to the Knowledge Economy typically hinges on efficient investments in education, public R&D expenditure, innovation capability and information infrastructure. These elements have been termed by the World Bank as the pillars of the Knowledge Economy and together constitute the Knowledge Economy framework.

The WBI knowledge for development report mentioned a number of studies which have shown innovation or generated technical knowledge which has had substantial positive effects on economic growth through efficient public R&D expenditure. For example, "Lederman & Maloney (2003), using regressions with data panels of five-year averages between 1975 to 2000 over 53 countries, finds that a one-percentage point increase in the ratio of total R&D expenditure to GDP increases the growth rate of GDP by 0.78 percentage points. Guellec & van Pottelsberghe (2001) investigated the long-term effects of various types of R&D on multifactor productivity growth using panel data for the OECD countries over the period 1980-98. They find that business, public and foreign R&D all has statistically significant positive effects on productivity growth[2]" (cited in Chen & Dahlman, 2005, p.06). Considering the above discussion of the existing KBE frameworks developed by OECD and WBI, our study found that the essence of long run sustainable growth in KBE develops through

[2] Guellec and van Pottelsberghe (2001) define public R&D as R&D performed by government and higher education sectors, and foreign R&D as business R&D performed in other 15 OECD countries.

Efficient public R&D investment

↓

Technological innovation

↓

Productivity increase

↓

Sustainable economic growth

Table 5.1: Studies on R&D efficiency which employs DEA method

Authors	Data sets	Inputs and outputs used in DEA model	Key results
Cullmann, Schmidt-Ehmcke & Zloczysti (2009)	OECD data base, PATSTAT	DEA on 30 OECD countries; Inputs: R&D expenditure and researchers, Outputs: Number of Patents	Germany, Sweden and United States- the most efficient countries; Mexico and China- low efficiency. High regulation in product markets lowers research efficiency in the economy.
Schmidt-Ehmcke & Zloczysti (2009)	OECD data base	DEA on 17 European countries; Inputs: R&D expenditure, high and medium skill labour, Outputs: number of patents	Small economies for instance Belgium, the Netherlands, Ireland) have high efficiency, while United Kingdom, France and Spain lag behind
Roman (2010)	2003 and 2005, EUROSTAT, National Institute for Statistics of Romania and Bulgaria	Inputs: R&D expenditure, Total researchers, output: Patents, scientific & technical articles, High-tech exports % of total	Both the countries show the DRS in knowledge production, Bulgaria is slightly better than Romania
EI-Fattah (2011)	World Development Indicators (WDI-1996 to 2008) data base	Inputs: R&D expenditure, Outputs: High-tech export and real GDP growth	Government of Egypt should expand more R&D expenditure to reach the optimum level. It is still underutilised.
Huggins & Izushi (2007)	In the year 2001	Inputs: R&D expenditure, labour productivity, average schooling, output: mobile phone users, internet users, PC penetration, Hi-tech export etc.	India, Indonesia, Thailand and China are inefficient countries due to outflow of human resources and Finland, Malaysia, Singapore and South Korea relatively efficient

DEA loom involves the application of the linear programming technique to trace the efficiency frontier. It was originally developed to gauge the performance of various non-profit organisations, such as educational and medical institutions, which were highly exigent to traditional performance measurement techniques like regression analysis due to complexity and often relations of multiple inputs and outputs, as well as the absence of price and non-comparable units which had to be taken into account. The principles of DEA date back to Farrel (1957). The recent series of discussions on this topic started with the article by Charnes, Cooper & Rhodes (1978).

Studies on cross-country R&D efficiency measurement which employed the DEA method are provided in Table 5.1. Surprisingly, by observing the literatures which used the DEA method, we found that none of the existing literature comprehensively addressed the efficiency measurement of public R&D expenditure in ASEAN-5 which is considered one of the world's fastest growing regions. This motivated us to extend the existing literature of DEA application by focussing on five ASEAN member countries, namely Indonesia, Malaysia, the Philippines, Singapore and Thailand.

5.2 Research framework

Since a firm length of time is required before R&D is completed and outputs are realised, it was necessary to take into consideration a time difference between inputs and outputs. Based on the empirical research of Cullmann, Schmidt-Ehmcke & Zloczysti (2009) and Monica Roman's (2010) working paper, this study set the time lag at 2 years. The input data set for 2008 was thus harmonised with the output data set for 2010. This paper measured the efficiency of public R&D expenditure by considering R&D expenditure as % of GDP as input. In addition to this, there were also two outputs, namely real GDP growth rate and high-tech goods (for instance, Information and Communication products (ICT), electronics goods, pharmaceutical and bio-tech products) export as % of total manufacturing exports. All data were collected from World Development Indicators (WDI- 2010), World Competitiveness Yearbook (WCY-2011) and ASEAN publications. Subsequently we applied the DEA method in order to measure the R&D efficiency.

We attempted to answer the question of, to what extent can output quantities can be altered without changing the input quantities used. Subsequently, we also investigated which scale size should be considered as the most productive scale size (MPSS) for inefficient countries. We applied the output orientation model in our study, and thus countries aim to maximise the R&D output resulting from their inputs. We estimated both the constant returns to scale model (CRS, Charnes et al., 1978) and the variable returns to scale model (VRS, Banker et al., 1984). The Scale efficiency in our study was determined by the difference between the CRS and VRS efficiency scores. The scale efficiency explains the optimal size and magnitude of the research production process in the countries.

5.3 Results and discussion

The degree of correlation between inputs and outputs is an important issue which can affect the robustness of the DEA model. Thus, a correlation analysis was essential to establish the appropriateness of our input and output choices in the analysis. Very high or low correlations between an input variable and output variable may give unexpected results. Correlation analyses were carried out for each pair of variables; the details of which can be found in Table 4.2. We did not find any evidence of a very high or low correlation between any one input variable and any other output variables in Table 4.2. As expected, our correlation matrix showed a positive relationship between the input and outputs variable. This is a reasonable validation of the DEA models according to EI-Fattah (2011). Below can be found some abbreviations for future discussion;

CCR = Charnes, Cooper and Rhodes original model
CRS= Constant Returns to Scale
BCC= Banker, Charnes and Cooper model
VRS= Variable Returns to Scale
IRS= Increasing Returns to Scale
DRS= Decreasing Returns to Scale
TSE = Technical and Scale Efficiencies
PTE= Pure Technical Efficiencies
SE=Scale Efficiencies
MPSS= Most Productive Scale Size

Table 5.2: Correlation matrix of inputs and outputs

	GDP growth rate	**High-tech exports as a % of total exports**	**R&D expenditure as a % GDP**
GDP growth rate	1	0.3843	0.4074
High-tech exports as a % of total exports	0.3843	1	0.0711
R&D expenditure as a % GDP	0.4074	0.0711	1

DEA analysis of the data presented in Table 5.3 was carried out using DEAP (Data Envelopment Analysis Programme) software, version 2.1 developed by Tim Coelli in 1996. Note that listed efficiencies should be viewed as relative to the best performing country in the particular year. Based on the rule of thumb of DEA, the number of DMUs should be greater than double the sum of inputs and outputs. Therefore, we add South Korea (a member of ASEAN and 3 additional countries) in order to produce robust results for DEA analysis.

Table 5.3: DEA model results

DMU	**TSE (CRS)**	**% of output that can be proportionally expanded without altering the input quantities used**	**PTE (VRS)**	**% of output that can be proportionally expanded without altering the input quantities used**	**Scale efficiency (TSE/PTE)**	**Returns to scale**	**MPSS/Peers/ Benchmarks**
Indonesia	1.000		1.000		1.000		
Malaysia	0.133	87%	0.798	20%	0.167	DRS	Philippines
Philippines	1.000		1.000		1.000		
Singapore	0.067	93%	1.000		0.067	DRS	
Thailand	0.438	56%	1.000		0.438	DRS	
South Korea	0.024	98%	0.567	43%	0.042	DRS	Philippines

The first and immediate result of the DEA calculations was an efficiency rating of each observation (here, country). A rating of 100% (or 1) indicates that the country is located on the efficiency frontier. However, an efficiency rating less than 100% signals non-optimal behaviour. A second set of calculations provides a measure of the *returns to scale* of each country. Theoretically, constant returns to scale (CRS) are said to exist at a point on the frontier if a 1% increase of all inputs leads to a 1% increase of all outputs. Decreasing returns to scale (DRS) are said to prevail if outputs increases by less than 1%, while increasing returns to scale (IRS) are present if they increase by more than 1%. Generally speaking, the DRS situation is associated with a mature economy where basic economic and social needs have already been covered, thus meaning that the incremental return of additional efforts is falling. In contrast with DRS, the IRS would seem to be associated with high productivity of production factors, where a nation can enjoy multiplying incremental returns on economic efforts, in our case the real GDP growth and high-tech exports. Our calculations of returns to scale have a direct interpretation in terms of KBE policy. In an obvious sagacity, a country with DRS in any KBE dimension is not using its KBE inputs optimally while a country with IRS can be expected to be engaged in rapid economic growth and higher KBE outputs. Both DRS and IRS are considered as inefficient scale sizes.

The optimal use of KBE resources is operating at CRS or scale size 1. We found from the DEA results (Table 5.3) that Indonesia and the Philippines were the most efficient countries, with 100% efficiency rating in 2010 under CRS assumption while Singapore, Thailand, Indonesia and the Philippines were the most efficient under VRS assumptions in the same year. The difference of 100% efficiency under two assumptions is because under variable return to scale we assumed that firms can face economies or diseconomies of scale. However, Indonesia and the Philippines were found to have the most productive scale size of 1 in 2010. All other countries showed decreasing returns to scale (DRS), thus implying that these countries are not operating their R&D expenditure in an efficient way. It would be possible for these inefficient countries to reduce R&D expenditure while still obtaining the same amounts (or more) of real GDP growth and high-tech exports. Inefficiency is often embedded in existing economic and social structures, such as weak entrepreneurial spirits, poor functioning of capital markets, disincentives created by tax codes, lack of modern equipment in research field and so on (Golany & Thore, 1997).

The question here seems to be, in such a case of inefficiency, if a DMU not operate at its Most Productive Scale Size (MPSS) i.e. 1, then what is its MPSS? That is, if the present scale of operation of a DMU does not lead to 100% scale efficiency, then what is the scale size it should operate at to achieve 100% scale efficiency? Mathematically speaking, the information relating to MPSS for an inefficient firm is contained in the weights of its Peers or Benchmark countries (Ramanathan, 2003). Table 6.3 also provides information about Peer or MPSS / Benchmarks for countries considered inefficient in the analysis. Peers are efficient countries with a performance score of 1 and all slacks 0.

Both Indonesia and the Philippines are considered to have the most productive scale size, although Indonesia is not taken as a benchmark for any other inefficient countries. This means that although both the countries are efficient, theoretically speaking, Indonesia must and can still improve its efficiency compared to the the

Philippines. Hence, from our analysis we found that Malaysia and S. Korea's peer is the Philippines, thus meaning that these two countries can try to emulate the Philippines by achieving better values of attributes, which could result in achieving the most productive scale size of 1. The Philippines was the largest manufacturer of high-tech products in 2010. Its % of high-tech products as % of total manufacturing export was 65.65.

We must point out that the variable we are concerned with is high-tech exports (US$ millions) *as a % of total manufacturing exports*. According to WCY-2012, Singapore, South Korea, Malaysia and Thailand had greater absolute value of high-tech exports measured in US$ millions than the Philippines. However, the Philippines had the greatest share of high tech exports as a percentage of manufactured goods exports. The Philippines' percentage of high-tech products in total manufacturing exports was 65.65%, followed by Singapore with 50.01%, Malaysia with 48.11%, Indonesia with 13.13% and Thailand with 27.12% (WCY-2012). In the case of Singapore, Malaysia and South Korea, total manufacturing exports are diversified and consist of both high and medium tech goods, including bio-technology, computer equipment, electronics products, motor vehicles, ship buildings and others; conversely, in the Philippines the semi-conductor industry alone comprises the largest share of both high-tech and total manufacturing exports of the country.

If we had considered the absolute value of high-tech exports as our reference variable we may have found a different picture. On average, the government provided 65.7% of the R&D expenditure in the Philippines during the period spanning 1996-2010 in an attempt to speed up the production of high-tech goods from FDI. In short, we can say that the Philippines' government agencies, universities and educated English speaking workers contributed to the efficient use of R&D expenditure to produce high value-added goods compared to neighbouring Indonesia, Malaysia and Thailand during the last decade or so (Nelson, 1993).

However, apart from emulation of peers, Malaysia, Singapore, Thailand and S. Korea can expand 87%, 93%, 56% and 98% of their output respectively without altering the input quantities used under CRS assumption. In addition, under VRS assumption, Malaysia with 20% and S. Korea with 43% can improve their real GDP and high-tech goods production without altering the current amount of R&D expenditure as a percentage of GDP. This implies that governments of respective countries should use R&D expenditure in an efficient way which yields the optimal outputs.

5.4 Conclusion and policy suggestions

This chapter demonstrates the importance of efficient use of public R&D expenditure by employing a linear mathematical model DEA. According to CRS assumption, Indonesia and the Philippines were the most efficient countries in 2010, with 100% efficiency ratings, while Singapore, Thailand, Indonesia and the

Philippines were the most efficient under VRS assumptions in the same year. The Philippines is considered as the benchmark or most productive scale size for Malaysia and S. Korea.

However, apart from emulation of peers, Malaysia, Singapore, Thailand and S. Korea can expand 87%, 93%, 56% and 98% of their output respectively without altering the input quantities used under CRS assumption. Under VRS assumption, Malaysia with 20% and S. Korea with 43% can improve their outputs i.e. real GDP and high-tech goods production without altering the current amount of R&D expenditure as a percentage of GDP. Finally, we can suggest that ASEAN-5 should assign more importance to the production of high-tech goods like ICT products, bio-technology, electronics, pharmaceutical etc. which require more knowledge than physical labour and capital. We believe that this will lead ASEAN nations towards the path of sustainable economic growth, thus meaning that they can become successful knowledge economies in the future.

5.5 Case study 2: Critical analysis of World Bank Knowledge Assessment Methodology (KAM)

The World Bank Institute (WBI) (1999) has developed the Knowledge Assessment Methodology (KAM) as a Knowledge-Based Economy (KBE) framework for its member states in order to specify their level of knowledge-based economic development. WBI (2002) stated in their framework that a knowledge economy (KE) is one of the key engines of long run economic growth. In this economy, knowledge is acquired, produced, diffused and utilised effectively to increase the wealth of nations. The KAM (www.worldbank.org/kam) benchmarks the countries relative to its neighbours or other parts of the world under different pillars of KAM. This methodology signifies the area of the knowledge economy on which a country should focus compared to its counterpart or best practice regions. According to the WBI KAM, the knowledge economy can be quantified by means of a numerical index known as the Knowledge Economy Index (KEI). While constructing the index, WBI ranks the countries based on the absolute values (raw data).

However, there are certain questions which arise while using this methodology for the member countries. For instance, at first, if a country wants to emulate other neighbouring countries to develop their knowledge economy performance, there is an issues regarding how the follower country selects which neighbouring country they should emulate, particularly if two or more neighbouring countries have the same ranking. Secondly, WBI did not explicitly define their KBE definition in relationship to how a country can acquire, produce, distribute and utilise their knowledge by using WBI variables. To investigate these questions, the present case study used Data Envelopment Analysis (DEA) and selected countries including Indonesia, Malaysia, Singapore, the Philippines, Thailand and South Korea as samples. Our research is expected to provide new insights in order to improve KAM for future analysis. To fulfil our above objectives, we split our analysis into four sections. Indeed, Section 1 presents a general introduction, whilst Section 2 describes the KAM vs. DEA methodology. Following this, Section 3 puts forth empirical results in an ASEAN-5 context and finally Section 4 draws conclusions and makes policy suggestions.

5.6 KAM vs. DEA methodology

The World Bank KAM Basic Scorecard provides an overview of the performance of a country in terms of the pillars of the knowledge economy under 5 sub-titles. Table 1A (Appendix-01) displays these indicators in detail. The basic scorecard is developed for constructing the Knowledge Economy Index (KEI) and the Knowledge Index (KI). The KEI index is built on the average performance scores of a country or region in all four pillars. According to Chen & Dahlman (2005) each of the variables used in the KAM is normalised on a scale from 0 to 10. The normalisation procedures of KAM use the raw data (u) to rank the countries in each and every one of the KAM variables. KAM calculates the number of countries with the lowest rank (Nw) divided by the total number of countries in the sample (Nc): Normalised (u) = 10*(Nw/Nc); this formula allocates a normalised score from 0-10 for each of the 121 countries with available data. Indeed, a score of 10 represents the top score for the top performers whilst 0 is the worst score and is assigned to the stragglers (an example of actual and normalsed values is given in Appendix B: Table B.2).

5.7 DEA methodology

There are vast similarities between KAM methodology and DEA. Data Envelopment Analysis (DEA) is a methodology leading an application of linear programming. It measures the efficiency of the Decision Making Units (DMU) by comparing them with the best producer in the sample so as to derive compared efficiency. Therefore, the fundamental objective of KAM and DEA is almost similar. Both the methods are used for the performance assessment of a country, firm or organisations. A distinctive feature of the DEA approach is that, for each DMU (e.g. an individual country), it calculates a single relative efficiency ratio by comparing total weighted outputs to total weighted inputs for each unit without requiring the proposition of any specific functional form. Unlike KAM, according to the original CCR (Charnes, Cooper & Rhodes, 1978) model, the DEA efficiency value has an upper bound of one and a lower bound of zero. Indeed, together with collected evidence, the two types of DEA models, namely the input-oriented and the output-oriented models, indicate that research results are not dependent on which of the models is being used (Hsu, Luo & Chao, 2005).

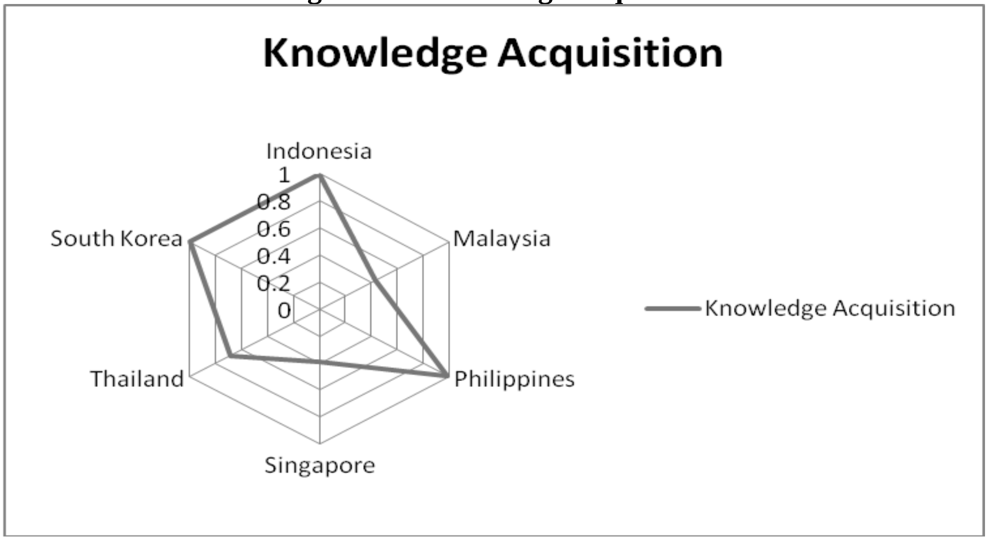
Charnes, Cooper & Rhodes (1978) have developed a mathematical transformation called the CCR (the initials of their names) model, which converts the nonlinear programming of efficiency ratio to a linear one under constant-returns-to-scale (CRS). Another important feature of DEA is to calculate the Most Productive Scale Size (MPSS) for the inefficient DMU. Mathematically speaking, in DEA calculation, the information regarding MPSS for an inefficient firm is contained in the weights of its Peers or Benchmark countries (Ramanathan, 2003). This is a unique feature compares to KAM and is designed to establish which countries should be emulated by the inefficient or low ranking countries. Hence, we can say that DEA can be used to improve KAM for future research. The next section will discuss the sample countries; investigate the WBI KBE definition and DEA results interpretation.

5.8 Empirical results and discussion

ASEAN-5 is the world’s fastest growing region and has the unique characteristics of a new economy. It has high growth rate, low inflation and is slowly becoming a technology driven economy. Appendix C: Table C.1 to C.15 gives the trend of 5 selected south-east Asian countries’ economic performances. Our paper therefore considered these countries for empirical analysis. However, before going into DEA calculation, we first formulated our policy-focussed KBE framework in order to apply the DEA method described in an earlier chapter. We built a policy focussed KBE framework based on the WBI (1999, 2002) KBE definition considering four knowledge dimensions under which there are four output variables and some selected input variables. The KBE input-output variables were selected from WBI KBE frameworks by observing timely data availability. Indeed, it was deemed that the data should be available for all the study countries for the reference year 2010 for the purposes of comparison (ABS, 2002; Afzal & Lawrey, 2012a, 2012b, 2012c, 2012d). This segregation of the variables under different knowledge dimensions is missing in KAM. However, this study applied the DEA approach by using the policy-focussed KBE framework for selected south-east Asian countries.

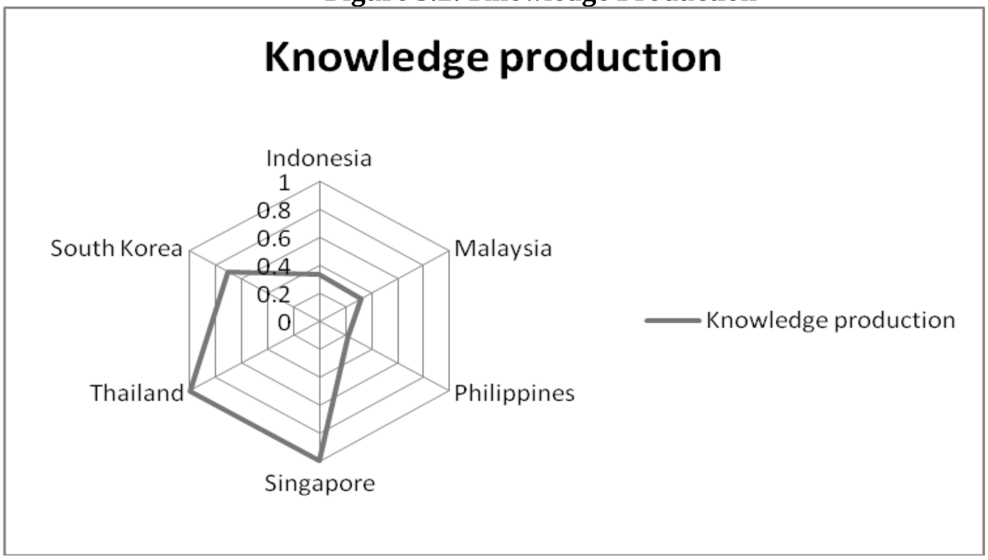
DEA analyses were carried out using DEAP (Data Envelopment Analysis Programme) and Efficiency Measurement System (EMS) software. Note that listed efficiencies should be viewed as relative to the best performing country. Based on the DEA’s rule of thumb, the number of DMUs should be greater than double the sum of inputs and outputs. With this in mind, we added South Korea, a member of ASEAN, together with three additional countries to produce robust results for DEA analysis. The results will follow the sequence of our policy focussed KBE framework. The following spider diagrams exhibit the knowledge economy performance of selected ASEAN economies and their benchmarks according to the DEA calculations.

Figure 5.1: Knowledge Acquisition



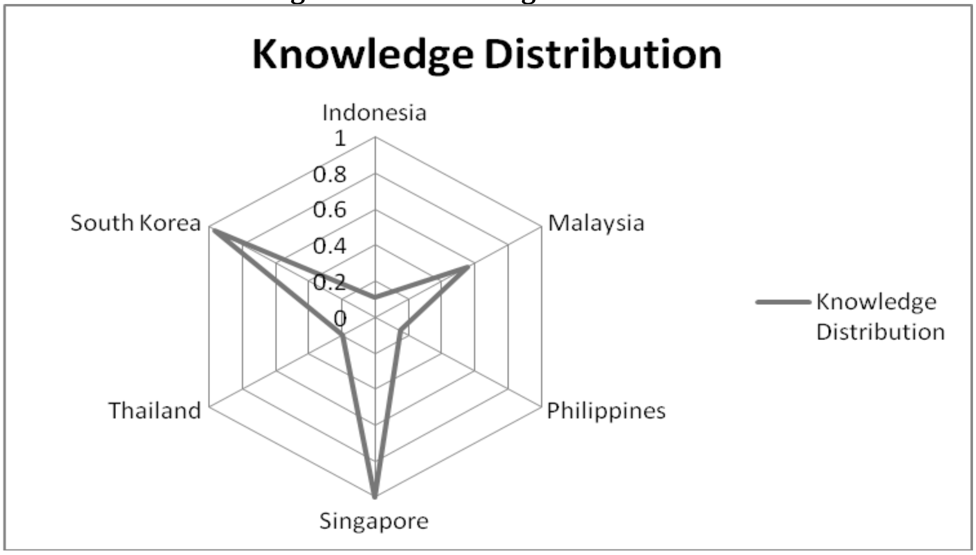
Best performing countries (efficiency score 100% or 1): Indonesia, South Korea
Benchmarks for the inefficient countries to emulate: Indonesia, South Korea

Figure 5.2: Knowledge Production



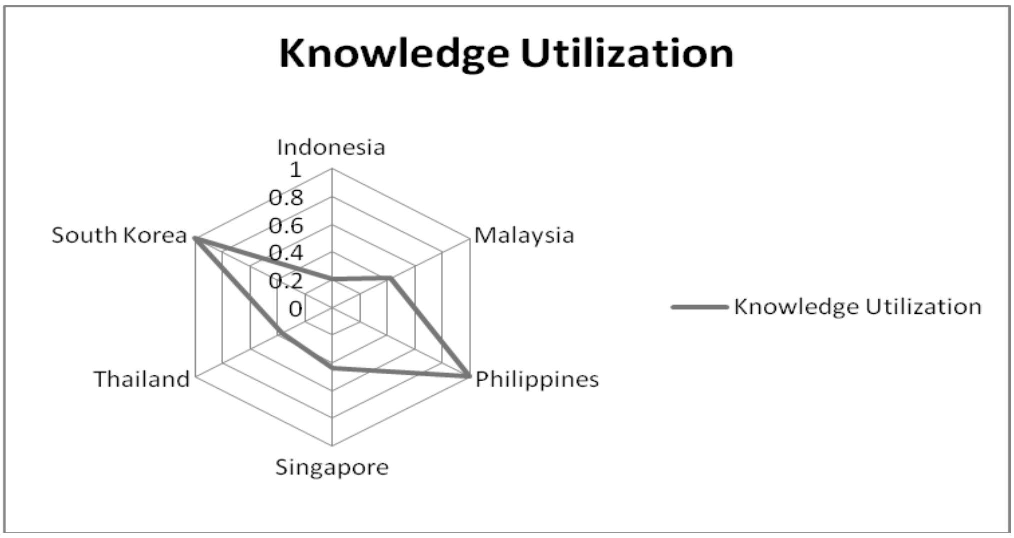
Best performing countries (efficiency score 100% or 1): Singapore, Thailand
Benchmarks for the inefficient countries to emulate: Singapore, Thailand

Figure 5.3: Knowledge Distribution



Best performing countries (efficiency score 100% or 1): Singapore
Benchmarks for the inefficient countries to emulate: Singapore

Figure 5.4: Knowledge Utilization



Best performing countries (efficiency score 100% or 1): Philippines, South Korea
Benchmarks for the inefficient countries to emulate: Philippines

The first and immediate result of the DEA calculations is an efficiency rating of each observation (here, country). A rating of 100% (or 1) in the CCR model indicates that the country is located on the efficiency frontier. However, an efficiency rating less than 100% in the CCR model signals non-optimal behaviour. The first spider diagram shows the results for the knowledge acquisition dimension, with Indonesia and South Korea exhibiting the highest efficiency scores in 2010. This indicates that these two countries are using their knowledge to acquire inputs-trade openness and FDI more efficiently than other members of ASEAN. However, from our analysis, it appears that other countries in this time period are showing inefficient use of their resources. This inefficiency for other member countries means that it would be possible for the inefficient countries to reduce without altering the use of its inputs while still obtaining the same amounts or more of the outputs in the knowledge acquisition dimension (Afzal & Lawrey, 2012c). Our results also yield information regarding Peer or MPSS/Benchmarks for countries considered inefficient in the analysis. Peers/Benchmarks are efficient countries with a performance score of 1, whilst inefficient countries score 0. Since both Indonesia and South Korea are considered to have the most productive scale size, other inefficient countries in the sample can try to emulate them by attaining better values of elements which would result in the most productive scale size of 1 (Afzal & Lawrey, 2012c).

The second diagram shows the efficiency score of the knowledge production dimension, with Singapore and Thailand representing the best performers in 2010 and also acting as benchmark countries for others.
According to the third spider diagram, Singapore achieves optimum efficiency in the referred time period. That is, Singapore is the best performer when it comes to the knowledge distribution dimension. Singapore set an example for other ASEAN as well as many developing countries by altering its geographical size and natural resource constraints. It did this by becoming a manufacturing base, producing increasingly technology and knowledge-intensive goods and increasing the use of ICT users in recent times (Yue & Lim, 2003). In 2010, their computer users comprised 827.48 per 1000 of the population, thus giving them an upper hand over many Asian economies in ICT use. Indeed, this allows countries to eventually disseminate knowledge faster and contribute to building a stronger knowledge base economy in the World (WDI-2010). With all of ths in mind, our calculation showed Singapore as the most efficient and benchmark country in this dimension in 2010 among the ASEAN member states.

Finally, from the last diagram, it is clear that the Philippines and South Korea scored 100% or 1 efficiency in the knowledge utilisation dimension. However, the interesting point is here is that both countries showed the same efficiency ranking, with the Philippines considered as the benchmark country for the inefficient members. Indeed, the DEA calculation implies that, of the inefficient countries, the Philippines had better weights or attributes than South Korea. As such, other inefficient countries along with South Korea can take the Philippines as their benchmark countries while formulating future optimsation policies. This is a unique feature of DEA in that it specifies which country can be taken as a peer or benchmark country for others.

We used FDI inflows as % GDP and knowledge transfer rate from university to industry (WCY-2011 executive survey based on an index from 0 to 10) as input variables. We also used high-tech export as a % of total manufacturing export as the output variable for this dimension. When explaining in terms of recent experience, we find that the Philippines is the largest manufacturer of high-tech products as % of total export in 2010. It exports mainly semi-conductor and electronic goods and its percentage of high-tech products as % of total manufacturing export was 65.65

followed by Singapore with 50.01, Malaysia with 48.11, Indonesia with 13.13 and Thailand with 27.12 in the same year (WDI-2010).

This implies that the Philippines is making optimum use of its FDI in flows in order to create new knowledge and ideas in the universities which eventually shift this knowledge to high-tech industrial growth. Theoretically speaking, investing in knowledge intensive sectors such as ICT, high-tech goods, bio-technology etc. can increase the productive ability of the other production factors whilst also converting them into new products and processes which guide a country towards increased efficiency in KBE (Afzal & Lawrey, 2012c; Lee, 2001). Hence, we can say that the other inefficient countries can emulate the best performing country in order to achieve optimum efficiency in respective knowledge dimensions.

5.9 Conclusion and policy recommendations

The results of our analysis have interesting policy implications with regard to improving KAM methodology. Our objective was to improve the existing KAM methodology by using the DEA technique. With this aim in mind, we investigated certain aspects of the KAM which are not clearly highlighted. For instance, in order to improve the KBE definition provided by KAM, we introduced a policy-focussed framework in which first we segregated the KAM variables under input-output indicators and distributed them among four knowledge dimensions, e.g. acquisition, production, distribution and utilisation. We considered 5 ASEAN countries as the sample for our study and subsequently applied the DEA technique to obtain the efficiency score of these countries in each knowledge dimension in 2010.

The interesting finding from the DEA calculation was that we were able to establish exactly which benchmark countries should be emulated by the inefficient economies by calculating the weights. In contrast, KAM suggested that the inefficient countries should follow the best performing countries, although in the case of similar ranking, it seems rather difficult to find which one to follow. KAM ranks the countries based on raw data of the variables while DEA ranks the best performing countries by calculating the efficiency score using weights. In case of ASEAN countries, Indonesia in the knowledge acquisition dimension, Singapore and Thailand in knowledge production, Singapore in knowledge distribution and the Philippines in the knowledge utilisation dimension were the best performing countries. This finding came from the use of DEA CCR assumptions in 2010.

Our research also revealed the benchmark countries in each knowledge dimension for selected south-east Asian countries. Indeed, the WBI KAM methodology can take this example and apply it to future research. We believe that our investigation will improve the KAM methodology and its policy suggestion regarding the growth of the knowledge-based economy for the client countries. The next two chapters will discuss national and regional innovation systems, its theories and the empirical investigation of ranking best practice countries and their innovation policies. Indeed, current KBE frameworks are lacking rigourous discussion of national and regional innovation systems. This provides the motivation for the present research to investigate and explain the two important innovation policy tools in more detail.

CHAPTER 6: NATIONAL INNOVATION SYSTEMS (NIS): CONCEPT, THEORY & EMPIRICAL ANALYSIS

Afzal, M. N. I. (2014). An empirical investigation of National Innovation System (NIS) using Data Envelopment Analysis (DEA) and the TOBIT model. *International Review of Applied Economics(IRAE), 28*(4) ***(forthcoming).***

And

Afzal, M. N. I., & Lawrey, R. (2013). National innovation system (NIS): An empirical investigation with robust non-parametric partial frontier analysis. *Margin- The Journal of Applied Economic Research* (under first revision).

6.0 Introduction

The National Innovation System (NIS) of a country is composed of different sub-systems ranging from the economic regime, financial structure and physical infrastructure to the education system, cultural traditions and so on. Thus, economic development is regarded as the interaction and co-evolutionary process of these sub-systems (Freeman, 1987; Nelson, 1993). Lundvall (1992, p.36) defined "the NIS as the elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge. He stated that they are either located within or rooted inside the borders of a nation state. In other words, the innovation system is defined as the network of agents and set of policies and institutions which affect the introduction of technology that is new to the economy.

NISs have been used as frameworks for clustering strategies in the context of encouraging existing networked industries to foster innovation for competitive growth (Porter, 1990). This approach is fundamentally rooted into two branches of economic theories, namely evolutionary economic theory and neo-institutional economic theory (Cai, 2011). Indeed, both of these theories argued that innovation and technology change are practiced as an endogenous process, thus meaning that new ideas are derived within the economic system rather than being introduced exogenously. Recently, many researchers have found certain shortcomings in the empirical application of NIS theories into practice. This is due to the fact that most of the NIS studies are theoretical and end up using a descriptive technique while other studies have used a small sample of countries to understand the innovation policy trends in a cross-country comparison (Balzat & Hanusch, 2004). This has motivated recent investigations to extend the NIS studies using robust parametric or non-parametric techniques to understand the application of NIS theories into reality.

Indeed, Furman et al. (2002) previously investigated a formal empirical analysis in NIS studies called 'national innovative capacity'. His empirical analysis was based on three NIS theories, including endogenous growth theory (see e.g. Romer, 1990), Porter's theory of international competitiveness (Porter, 1990), and the national systems of innovation introduced by Lundvall (1992). Furman's national innovative capacity illustrated a country's innovation ability to produce and commercialise new ideas over a long period of time. He also argued that innovation culture depends on the strength of a nation's common innovation infrastructure, industrial clusters, and the strength of linkages between these two. He also used a number of variables to quantify these three components of innovation in his empirical analysis (Cai, 2011). However, this approach has been criticised for its small variable size, and the small sample used in the empirical analysis. Nevertheless, after his study, considerable progress has been made in the empirical study of NIS (Balzat & Hanusch, 2004). Having observed the existing NIS literature (According to Appendix B: Table B.4) we believe there is still much room for further improvement in terms of the NIS approach using robust empirical methods. In order to fill this gap in the empirical study of NIS, the present study applied a robust nonparametric partial frontier order-α and bootstrapping analysis to measure the innovation performance of 20 selected emerging and developed economies. The objective of this method was to measure the comparative efficiency of a set of potential innovation input-output variables.

DEA (Data Envelopment Analysis)/FDH (Free Disposal Hull)/Partial frontier analyses are non-parametric methods and do not require a pre-specified functional form to analyse the efficiency of a particular Decision Making Unit (DMU). Here, the countries, and the Partial frontier order-α and bootstrapping technique in particular, improve the DEA/FDH analysis by correcting bias and outliers in the data. Therefore, we considered these new methods for rigorous analysis. Our approach can be used to rank the best practice countries using potential influencing NIS input-output factors whilst we also believe that in order to follow a successful innovation policy, there is a need to benchmark best practice innovation systems from cross-country comparison and analyse their innovation policies. With this aim in mind, the present chapter is split into 6 sections; following the introduction, a theoretical review of NIS is presented in Section 6.2, whilst the research design and methodology is summarised in Section 6.3. Following this the data and variables used are presented in Section 6.4, whilst the results and discussion can be found in Section 6.5. Finally, Section 6.6 introduces the TOBIT model to explain inefficiency before Section 6.7 draws conclusions and puts forth policy implications.

6.1 Theories behind NIS approach

Any innovation concept can be rooted back to the work of Schumpeter (1942), who argued that the innovation process flows through a concept called ‘creative destruction’, meaning the introduction of new products, processes, and techniques, with new markets in the economic system always replacing the old ideas and continuing with the interaction of different economic agents. His concepts were supported by heterodox economic theories including evolution theories, neo-institutional theory and the endogenous growth model. These theories supported the argument of Schumpeter and postulated that innovation is a non-linear process in contrast with linear orthodox economic theory. Different phases of innovation processes are inter-linked and they do not end when the diffusion/imitation phase is completed (OECD, 2002). Rather, innovative activities have continued with the interaction of various actors including individual researchers, universities research facilities, government policy and local firms. Indeed, all of these bodies are trying to create and commercialise new ideas to satisfy the customers at a later phase of the whole innovation system (Nelson, 1993; Metcalfe, 1995). Due to this non-linear nature of the innovation system, we use the non-parametric technique to investigate the nature and ranking of best practice countries in the NIS context.

6.2 Research design and methodology

In this particular study, we applied the conditional partial order-α *(alpha)* frontier approach and later the bootstrapping technique to rank the best practice countries. Nonparametric approaches generally have a clear advantage as the estimated functions can take almost any form. In addition, it is often difficult to describe real world observations in a single dimension or dependent variable as the core definition of NIS has suggested that innovation is not a linear phenomenon, but rather a combination of institutions and their variables. Hence, one of the strengths of the Non parametric technique is that it allows for an easy handling of multiple input factors as well as multiple innovativeness outcome or output factors. In contrast, the consideration of innovativeness measures as multiple dependent variables is particularly diffucult to achieve by relying on the conventional regression technique (Brökel, 2008).

6.2.1 Order-α partial frontier approach

We discuss this technique in a non-technical way so that common readers can understand the concept. In contrast with the FDH or DEA approach (for more information about the DEA/FDH technique see Charnes, Cooper & Rhodes, 1978; Banker, Charnes & Cooper, 1984; Afzal & Lawrey, 2012b, 2012c, 2012d), the idea behind the order-α partial frontier approach is that Order- α follows the mechanism of FDH/DEA methods, yet in a different way. Rather than using minimum input consumption among the available peers as a benchmark, order- α uses the (100-α)th percentile. For α= 100 order- α coincides with FDH, while for α < 100 some DMUs will be classified as 'super-efficient' and these super-efficient DMUs are not be enveloped by the estimated production possibility frontier. That is, just like *m* for order-*m* efficiency estimate, α can be regarded as a modified parameter which determines the number of super-efficient DMUs. Since calculating order- α efficiency scores does not involve a re-sampling procedure like order-m, this method is much faster and smoother (see Aragon et al., 2005; Daouia & Simar, 2007).

The advantages of order- α Non-parametric efficiency analysis include:

1. Sensitivity to outliers reduced by allowing for super-efficient DMUs

2. Super-efficient DMUs located beyond production-possibility frontier

3. Super-efficiency: (input-oriented) efficiency score > 1 (in our case)

4. Increasing the value of α reduces number of DMUs classified as “super-efficient”

5. In the absence of outliers: share of super-efficient DMUs should decrease smoothly

Because the partial frontier (e.g. order-α) is not enveloping all observations, it is less sensitive to outliers and noise in the data and solves the well-known problem of 'curse of dimensionality' which often plagues non-parametric estimators (Wheelock & Wilson, 2008). Mathematically speaking, two efficiency estimate looks like;

Order-alpha input-oriented efficiency:

$$\hat{\theta}_i^{Ainput} = P_{\substack{100-\alpha \\ j=1,\dots,N|yIj\geq yIi\forall I}} \{\max_{m=1,\dots M}\{\frac{X_{mj}}{X_{mi}}\}\}$$

Order-alpha output-oriented efficiency:

$$\hat{\theta}_i^{Aoutput} = P_{\alpha\; j=1,\dots,N|X_{mj}\leq X_{mi\forall m}} \{\min_{i=1,\dots L}\{\frac{Y_{Ij}}{Y_{Ii}}\}\}$$

6.3 Data and variables

The influencing factors of NIS efficiency (Table 6.1) involve many elements, including demographic structure, ICT infrastructure, firm-level and government R&D and innovation activities, economic and market size, trade openness, reliance on natural resources, financial structure, market circumstance, and government level. This conforms to the relevant arguments of the NIS approach and the New Growth Theory (Balzat & Hanusch, 2004). The firm is the most active and important factor when it comes the process of commercialising innovation, which is represented by the output variable high-tech exports as a % of total manufacturing exports. The more firms which are involved in R&D and innovation activities, the better the NIS efficiency would be. This is according to the arguments of the Austrian school and Lundvall (1992), who argued that the free interaction of knowledge can create and disseminate economically useful knowledge which develops the wealth of nations (Afzal & Lawrey, 2012a). Schumpeter termed this process the creative destruction of innovation process.

Table 6.1.Potential influencing factors for NIS efficiency and their proxy input-output indicators for year 2010

Input factors	Proxy Indicators	Abbreviation	Source of variable
Demographic structure	Population ages 15 to 65 (% of total) as labour force	Lab	World Development Indicators (WDI) 2010
ICT infrastructure	Computer users per 1000	CU	World Development Indicators (WDI) 2010
Financial structure	Domestic credit provided by banking sector (% of GDP)	DCP	World Development Indicators (WDI) 2010
Research and Development	R&D expenditure % GDP	RDE	World Development Indicators (WDI) 2010
Education	School enrollment, secondary (% gross)	SE	World Development Indicators (WDI) 2010
Market circumstance	Cost of business start-up procedure (% of GNI per capita)	CBS	World Development Indicators (WDI) 2010
Governance	Regulatory quality	RQ	World Competitiveness Yearbook (WCY) 2010
Openness	Trade (% of GDP)	TO	Penn Table version 0.7
Natural Resources endowments	Total natural resources rents (% of GDP)	TNR	World Development Indicators (WDI) 2010
Output indicator			
Economically valuable knowledge creation	High-tech export as % total manufacturing exports	HTE	World Development Indicators (WDI) 2010

The age structure of the population affects NIS efficiency, because young people are thought to be more creative than the old people. ICT infrastructure and trade openness would affect the speed and scope of knowledge diffusion and in turn affect NIS efficiency. Furthermore, economic size and degree of openness determine the scale of domestic and international markets for firms. Economies of scale and economies of scope can be achieved much more easily in a bigger market, and can in turn have an indirect influence on NIS efficiency (Balzat & Hanusch, 2004). Moreover, overdependence on natural resources would reduce innovation capacity and NIS efficiency.

A recent study indicated that, in general, patent activity, publications per 1000 of population and high-tech export variables are considered as output factors of NIS (Kotsemir, 2013). However, the core idea of evolutionary or national/regional innovation system theories revolves around knowledge flows within the whole system by interacting with different micro and macroeconomic agents including research institutes, government, universities, venture capitalists etc. The innovation does not follow a linear model, but rather continues in a non-linear direction from the non-commercial sector to the commercial sector (ABS, 2002; Johnson & Lundvall, 2003). Therefore, in this study we considered high-tech export as % of total manufacturing export as an NIS output indicator to represent commercialisation or economically value added knowledge.

Institutions like property rights, transparent government, political stability, a dependable legal & regulatory system, and competitive and open markets drive the generation of technological knowledge in best practice countries. This is a very important issue in terms of creating new ideas with which to generate more wealth of the nations (Hailin, Xiaohui & Chengang, 2012; Marion & Grazia, 2007; Cowen & Tabarrok, 2009). Our sample of 20 emerging knowledge-based countries have moderately common characteristics of dependable regulatory quality and high degrees of trade openness. This motivated us to examine how the efficiency scores vary among the countries while they have a moderate regulatory quality and high trade openness in NIS systems. Table 6.2 shows the descriptive statistics of our sample year 2010 (cross-section sample). In previous studies (Afzal & Humayara, 2013; Afzal & Lawrey, 2012c) we applied DEA time series analysis with similar sorts of variables. Following this, and due to the availability of most recent data pertaining to all of the countries, we preferred 2010 as our reference year in this study.

Table 6.2: Descriptive statistics of the input-output variables

	TO	TNR	SE	RQ	RDE	LAB	HTE	DCP	CU	CBS
Mean	116.0	3.4644	88.63	5.38	1.98	67.30	21.71	130.78	565.73	9.2950
Median	88.720	2.343	92.23	5.02	1.97	67.0	16.09	132.8	798.91	3.300
Maximum	409.2	13.14	103.2	7.89	3.96	73.58	67.82	325.9	937.8	56.50
Minimum	29.31	0.0000	63.21	2.90	0.08	60.9	1.9	36.4	39.7	0.0
Std. Dev.	106	3.9	11.9	1.6	1.2	3.2	16.2	66.8	372.4	13.4
Observations	20	20	20	20	20	20	20	20	20	20

Source: Author's calculation

6.4 Results and discussion

The results presented in Table 6.3 on the following page are generated by a software program, namely FEAR (Frontier Efficiency Analysis with R) which implements the conditional and unconditional order-α partial frontier analysis developed by Simar & Wilson (1998).

The efficiency scores were estimated using an input oriented order-α with 9 inputs and 1 output. The decision making units (DMU) with efficiency scores of > 1 are 'super- efficient' while DMUs with scores less than this are inefficient.

Table 6.3: Efficiency scores *(FEAR software results)*

Ranking/ Benchmarks	Country	Order-α= 0.85	Ranking/ Benchmarks	Country	Order-α= 0.90
1	**Singapore**	**1.12**	1	**S. Korea**	**1.03**
2	**China Mainland**	**1.004**	2	Hong Kong	1.00
3	**S. Korea**	**1.002**	2	Japan	1.00
4	Malaysia	1.00	2	China Mainland	1.00
4	Philippines	1.00	2	Malaysia	1.00
4	Switzerland	1.00	2	Philippines	1.00

7	Sweden	0.75	2	Singapore	1.00
8	Norway	0.70	2	Taiwan	1.00
9	Finland	0.67	2	Switzerland	1.00
10	Hong Kong	0.66	10	Thailand	0.82
11	New Zealand	0.55	11	Sweden	0.75
12	Australia	0.46	12	Finland	0.71
12	India	0.46	13	Norway	0.70
14	Taiwan	0.38	14	India	0.68
15	Brazil	0.34	15	New Zealand	0.57
16	Japan	0.32	16	Indonesia	0.52
17	Thailand	0.31	17	Australia	0.50
18	Indonesia	0.27	18	Brazil	0.43
19	Turkey	0.17	19	Turkey	0.18
20	Denmark	0.001	20	Denmark	0.0012

Source: Author's Calculation

Theoretically speaking, if we increase the value of α, this reduces the number of DMUs classified as "super-efficient" (Daouia & Simar, 2007). With this in mind, we have selected α=0.85 and 0.90 respectively in order to observe the theoretical relevance in our sample countries. In cases where α=0.85, the number of super-efficient countries was 3, including Singapore, China and South Korea, while in the case of α=0.90, the number was reduced and South Korea stood as the sole super-efficient DMU/country. The least three efficient countries in α=0.85 were Indonesia, Turkey and Denmark while Brazil, Turkey and Denmark were the bottom 3 in α=0.90. This is an interesting empirical finding, as the efficiency scores and rankings change not only for the top or bottom 3 countries, but also for other countries in the sample when α=0.90. Hence, we ranked our countries according to α=0.90,as it is apparently less sensitive to outliers.

This is an important finding for national innovation policy analysis using a robust empirical analysis. Indeed, it is essntial to have a robust empirical study because if innovation follower countries improve their efficiency, they need to know how they are positioned in terms of NIS performance. Moreover, in order to improve NIS efficiency, followers can pursue the innovation policies of the frontier countries or innovation leaders by using NIS input-output variables. In future studies, we can take this new non-parametric *order-α* application into a larger sample and assess the way in which efficiency varies across countries.

At this point we now focus on some notable NIS policies taken by our best practice/benchmark countries using the potential NIS input-output variables. For instance, during its initial stage of NIS, Japan focussed on 3 major components e.g. education expenditure and enrollment, reverse engineering and joint ventures with western companies. They created a group of business clusters known as *Keiretsu*, whereby the government deliberately favoured them with subsidies, bank loans and infrastructure facilities. These business clusters are known as the successors of the pre-war *Zaibatsu* regime. South Korea followed a similar strategy to the Japanese at the initial stage of its development during the 1960-70 periods when the Koreans formed a cluster of large firms called *Cheaboll* which was strongly supported by the government.

Cheaboll is a group of business associations which are controlled by the large family-oriented businesses which have strong ties to the government. They enjoy easy access to domestic and foreign loans, investment and special treatment by the government. During President Park Chung Hee's regime, Korea had a policy of import substitution and followed the winner takes all approach. Park Chung Hee relied solely on successful business companies and favoured them accordingly. Due to his initiatives and support, the *Cheaboll* group rose and contributed significantly to Korea's emerging economy. Samsung, LG, Golden Star and Hyundai are the result of South Korea's Cheaboll project (Nelson, 1993).

Unlike Japan and South Korea, China and Taiwan rely on SMEs which have also been supported by the government (Rosenberg, 2013). The Government of China formed a strong relationship with R&D institutions such as universities and high-tech export firms to develop their NIS. This strategy is often called the Triple Helix model of innovation. It was introduced by Leydesdorff (2006) and also supported by famous NIS researchers Lundvall, Nelson & Cooke. They suggested that the late comers should emulate this model to become leaders of innovation. Japan, South Korea and China all followed a form of government guided capitalism at their initial stage of NIS development using the best employ of NIS input-output variables. This strategy is in contrast with the Austrian and classical schools of relying on the free market mechanism. It cannot be denied that these three countries have achieved remarkable economic growth and have subsequently become the leaders of NISs.

However, Switzerland has followed a freer market strategy which has also made them innovation leaders (Johnson & Lundvall, 2003). From this evidence, the extent to which the government is involved in the economy does not appear to be critical. Indeed, of more importance is to develop suitable NIS polices which fit current economic conditions and address the NIS components which will allow innovation inputs to be transformed into innovation outputs in the most efficient manner. Additionally, we believe that the efficient use of NIS input-output variables which we highlighted in our study can lead to overall economic development. This development could take the form of creating employment opportunities, increasing skilled human resources, widening market for high-tech products by high degree of trade openness, maintaining good financial structure and spurring ICT driven growth. Our best practice countries of South Korea and Singapore initially followed the policies of frontier regions in NIS e.g. Silicon Valley, Route 128 or Japanese *Keiretsu* cluster models to build a similar kind of strategy in their respective countries. Hence, our methodology and policy discussion also indicated that there is a need of frontier analysis for successful NIS policy implication in the follower nations.

6.5 Determinants of efficiency in countries' NIS by using bootstrap and TOBIT model

6.5.1 Bootstrap technique

The idea behind the Bootstrap technique is to use the sample data set in the study as a proxy population, meaning the replacement of the actual population for the purpose of smooth sampling distribution. The Bootstrap creates a large number of artificial samples in order to draw a Bootstrap distribution of the statistic. In most cases the process simulates a large number of copies of a sample statistic, computed from these spook Bootstrap samples. Following this, a small percentage, say 100(α/2) % (usually, α= 0.05), is trimmed off from the lower as well as the upper end of these numbers. The range of remaining 100(1-α) % values is declared as the confidence limits of the corresponding unknown population summary number of interest, with level of confidence at 100(1-α) %.

6.5.2 Bias correction by Bootstrap

The mean of sampling distribution of $\dot{\theta}$ often differs from θ, usually by an account = c/n for large n. In statistical language, one writes:

$$\dot{\theta} = E(\dot{\theta}) - \theta \approx O(\frac{1}{n})$$

A Bootstrap based approximation to this bias is:

$$\frac{1}{N}\sum_{i=1}^{N}\theta_i^* - \dot{\theta} = B\hat{i}as_B\dot{\theta}(say)$$

where $\overset{*}{\theta}$ are Bootstrap copies of $\dot{\theta}$, as defined earlier. Thus the Bootstrap bias corrected estimator looks like $\dot{\theta}_c = \dot{\theta} - B\hat{i}as_B(\dot{\theta})$ (Singh & Xie, 2003).

In a recent paper on national innovation efficiency measurement, Jiancheng Guan & Kaihua Chen (2011) found that their efficiency scores were flawed due to possible statistical noise and outliers in the data. They therefore suggested the use of the bootstrapping procedure developed by Efron & Tibshirani (1993) and added to by Simar & Wilson (1998, 2000) to improve the estimation, reduce outliers, extreme points and statistical bias in the data. Hence, we applied the bootstrapping technique in an attempt to obtain a robust estimation of the efficiency of our research.

6.5.3 Results and discussion

The results presented in Table 6.4 were generated using two software programs. The first is the FEAR (Frontier Efficiency Analysis with R) which implements the homogenous bootstrap algorithm described by Simar & Wilson (1998), while the DEA efficiency scores come from DEAP (Data Envelopment Analysis Program), version 2.1 developed by Tim Coelli in 1996. The Bootstrap estimates were produced using B=2000 Bootstrap replications. Table 4 displays the results of the homogenous Bootstrap algorithm, giving the original efficiency estimates as well as the bias corrected estimates and the variance for year 2010.

The efficiency scores were estimated using a variable returns to scale, output oriented DEA with 9 inputs and 1 output. The decision making units (DMU) with efficiency scores equal to 1 were efficient while DMUs with scores greater or less than 1 were inefficient. Theoretically speaking, constant returns to scale (CRS) were said to exist at a point on the frontier if an increase of all inputs by 1% led to an increase of all outputs by 1%. Decreasing returns to scale (DRS) were said to prevail if outputs increased by less than 1%, while increasing returns to scale (IRS) were present if they increased by more than 1%. Generally, a DRS situation is associated with a mature economy where basic economic and social needs have already been covered, thus meaning that the incremental return of additional efforts is falling (Afzal & Lawrey, 2012b).

Table 6.4: Efficiency scores *(FEAR and DEAP results)*

Country	CRS	VRS	Scale	Bias corrected scores	variance
Australia	1	1		0.994	0.00017
China Mainland	1	1		0.994	0.00017
Hong Kong	0.489	1	IRS	0.994	0.00016
India	0.229	1	IRS	0.994	0.00016
Indonesia	0.320	1	IRS	0.994	0.00016
Japan	1	1		0.998	0.00019
Korea	1	1		0.997	0.00017
Malaysia	0.753	0.940	IRS	0.937	$1.61e^{-05}$
New Zealand	0.861	1	IRS	0.994	0.00017
Philippines	1	1		0.994	0.00016
Singapore	1	1		0.994	0.00018
Taiwan	1	1		0.997	0.00018
Thailand	0.993	1	IRS	0.995	0.00017
Denmark	1	1		0.994	0.00015
Finland	0.623	1	IRS	0.994	0.00016
Norway	0.854	1	IRS	0.994	$5.26e^{-05}$
Sweden	0.853	1	IRS	0.995	0.00017
Brazil	0.496	1	IRS	0.994	0.00015
Turkey	0.119	1	IRS	0.994	0.00020
Switzerland	1	1		0.997	0.00015

Most of the countries in our calculation (Table 6.4) exhibited efficiency = 1 under the VRS assumptions, with the exception of Malaysia; in contrast, Australia, China, Japan, South Korea, Philippines, Singapore, Taiwan, Denmark and Switzerland were the most efficient countries under the CRS assumption. However, according to bias corrected score none of the countries were fully efficient, although they were very close to efficiency. These near efficiency scores imply that these countries have an adequate combination of NIS components which can produce economically useful innovation. However, Japan, South Korea, Taiwan and Switzerland had slightly improved efficiency scores (0.998,0.997,0.997,0.997 respectively) in bias corrected column while Hong Kong, India, Indonesia, Malaysia, New Zealand, Turkey, Finland, Norway, Sweden, Brazil and Thailand demonstrated increasing returns to scale (IRS) which implies that there is the possibility to improve NIS efficiency with their current input-output resources.

6.5.4 Explaining inefficiency by Tobit model

According to Porter (1990), unlike the regional innovation system which is largely based on a cluster approach, the national innovation system is a broader concept. Researchers have found that the growth of NIS depends on some key macroeconomic variables and is controlled by central government innovation policy (Nelson, 1993; Dosi, 1998; Lundvall, 1992; Edquist, 1997). For instance, NIS researchers have mentioned in several studies that openness, FDI, public R&D expenditures; education enrollment, ICT infrastructure, financial infrastructure etc. are the key determinants of NIS as well as improving national competitiveness (Lundvall, 1992; Edquist, 1997; Porter, 1990). However, these variables are not equally important for our sample countries. In order to understand the significance of important variables in developing national innovation system growth, further investigation is essential. Policy makers of our sample countries need to know which variable has a direct effect on the efficiency score, thus helping them to formulate future policy recommendation for the country's national innovation system. With this in mind, in our paper we applied the TOBIT regression model to further investigate the effects of our sample variables on the DEA CRS technical efficiency results. Efficiency scores calculated by the DEA model were censored at 1; an Ordinary Least Square (OLS) estimate might produce biased and inconsistent parameter estimates. Tobit analysis considers a number of dependent variable values clustered at a limiting value. For this reason, we used the Tobit model to determine the effect of influencing variables on the country's DEA efficiency score. It is an approach which is used in the literature and which applies DEA, thus leading to almost identical results with other types of models (Greene, 2008; Liu, Chu & Liao, 2013).

The Tobit model is also known as the truncated or censored regression analysis model. The stochastic model in the original Tobit model may look like:

$$y_t = X_t\beta + \mu_t \qquad \text{if } X_t\beta + \mu_t > 0$$

$$= 0 \qquad \text{if } X_t\beta + \mu_t \leq 0,$$

$$t = 1, 2, \ldots, N,$$

where N represents the number of observations, y_t is the dependent variable, X_t is the vector of independent variables, β is a vector of unknown coefficients, and μ_t is the independently distributed error term assumed to be normal with 0 mean and constant variance $N(0, \sigma^2)$. We define inefficiency score as: Inefficiency score = 1- efficiency score (from DEA CRS efficiency results) and only fully efficient countries in our model (equation 1) have $E_i = 0$ values. The Tobit model estimates by following the maximum likelihood method assuming normal distributed errors μ_i. The technical efficient function of the National Innovation Systems of sample countries is written as Equation 1:

$$E_i = \alpha + \beta_1 TO_i + \beta_2 DCP_i + \beta_3 SE_i + \beta_4 CU_i + \beta_5 LAB_i + \beta_6 RQ_i + \beta_7 RDE_i + \beta_8 CBS_i + \beta_9 TNR_i + \mu_i \text{ ....eq(1)}$$

where E_i indicates the DEA CRS technical efficiency scores, *TO, DCP, SE, CU, LAB, RQ, RDE, CBS* and *TNR* are the independent variables (see Table 6.1), *i* indicates the number of countries or DMUs, α indicates a constant term, β1- β9 indicates the coefficients of independent variables and μ indicates an error term which $\mu \sim N(0, \sigma^2)$. The empirical results analysed by the Tobit regression model are shown in Table 6.5.

Table 6.5: Tobit regression results

Variable	Coefficient	Std.Error	z-Statistic	Prob
Constant	7.47	2.75	2.70	0.0068**
TO	-0.0010	0.001	-0.92	0.3536
TNR	-0.003	0.022	-0.133	0.89
SE	0.03	0.01	2.82	0.0047**
RQ	0.11	0.10	1.13	0.2582
RDE	0.048	0.177	0.27	0.7856
LAB	0.06	0.031	1.98	0.047**
DCP	0.004	0.002	1.91	0.055**
CU	0.00040	0.00058	0.77	0.439
CBS	-0.009	0.010	-0.939	0.34

** indicate 5% level of significant

According to Table 6.5, three variables, namely secondary school enrolment, labour force as % of total population and Domestic credit (SE, LAB, and DCP) were statistically significant at the 5% level whilst others were showing non-significance both at the 5% and 1% levels. Although Total Natural Resources Rent (TNR), Regulatory Quality (RQ), R&D expenditure (RDE), Computer users (CU) and Cost of doing business were not statistically significant, they came with the expected sign. Trade Openness was insignificant with the wrong sign, which may be because of an endogeneity problem. Others, for instance total natural resource rent (TNR), showed a negative sign, thus meaning the higher the dependence on natural resources, the lower will the efficiency of the NIS. In addition, regulatory quality (RQ) and research and development expenditure (RDE) had positive signs, thus implying that these two variables positively affect the growth of innovation.

The computer user variable had a positive sign, although it was insignificant, thus implying that ICT infrastructure contributes to the development of NIS. Finally, the cost of doing business variable came with a negative sign implying that the longer it takes to start up a business venture, the poorer the efficiency of NIS in our sample countries. The negative relationship of the cost of doing business in respect to efficiency represents bureaucratic disturbance.

When secondary school enrolments (SE) rose 3%, the efficient scores would increase to 100%, thus meaning that SE, in our model, can positively and significantly improve the efficiency scores of NIS. This variable also indicates the development of human resources in the country. Our model also showed that a 6% increase in the labor force (LAB) can increase the NIS efficiency score to 100% in our study countries. In any country, the labour force (aged 15-65) is an important indicator of the production function, thus improving the growth of innovation and sustainability. Finally, from our model, a 0.4% increase in domestic credit expansion by the business sector as a % of GDP (DCP) can positively and significantly lead to 100% efficiency score in the study countries. Domestic credit expansion by the business sector can also enhance investment in different sectors and thus improve the infrastructure of the country, which is also favourable to build a solid national innovation system in the country.

In conclusion, based on the Tobit regression model, the DEA CRS technical efficiency score of inefficient countries could be improved through three main variables, namely the Secondary School Enrolment (SE) ratio, the labour force (LAB) aged 15-65 as a % of total population and domestic credit expansion by the business sector as a % of GDP (DCP). Hence, from our analysis, these variables have a direct effect on increasing the technical efficiency score of NIS for the inefficient countries.

6.6 Concluding remarks

It is essential for policy makers to evaluate how their countries position themselves in NIS input-output combinations, in terms of achieved efficiency in relation to other countries. Thus, we have used the most recent nonparametric techniques such as the bootstrapping method and order-α partial frontier efficiency scores. These have assisted us in explaining which are the most efficient countries in NIS combinations from our data sample. We have also highlighted certain strategies employed by innovation leaders, or efficient countries, while developing their national innovation systems. Inefficient countries could study these strategies and the policies of the most efficient countries in order to improve their ability, and thus to transform NIS innovation inputs into NIS outputs. Policy measures should be directed to the efficiency performance of NIS activities in the transformation of knowledge economies. If innovation resources are underutilised, then further investment in innovation input factors may offset the efficient economic progress.

It is hoped that this research will provide an overview of the current trend of national innovation system research, make policy suggestions for the less than efficient countries, and offer a robust non-parametric *order-α* partial frontier and bootstrapping approach with which to identify best practice nations in the NIS context. Indeed, this paper has argued that a partial frontier such as *order-α* approach is more applicable for analysing a national innovation system framework than a traditional FDH (Free Disposal Hull) approach due to the advantage of overcoming outliers or extreme points from the sample.

By using the Tobit model we have explained the causes of inefficiency in our sample countries and thereby identified ways to improve the efficiency in innovation systems. Based on the Tobit regression model, the DEA CRS technical efficient score of inefficient countries could be improved through three main variables, namely the secondary school enrolment ratio, the labour force aged 15-65 as a % of total population and domestic credit expansion by the business sector as a % of GDP. We applied a cross-section approach and used the latest dataset from World Development Indicators-2011, World Competitiveness Yearbook-2011 and Penn world table for our analysis.

We believe that due to the application of the new non-parametric technique, the results of our study are reliable and that this could be taken into account for future policy formation to enhance the development of national innovation systems. Future work could attempt to employ order- m or hyperbolic order-α frontier estimation with a large sample of countries in order to examine how efficiency differs among countries and the effect of this on the reduction of outliers and extreme points in the data whilst conducting empirical studies on national innovation systems.

CHAPTER 7: ARE SCIENCE VALLEYS AND CLUSTERS PANACEA FOR A KNOWLEDGE ECONOMY? AN INVESTIGATION OF REGIONAL INNOVATION SYSTEM (RIS)

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7.0 Introduction

The Regional Innovation System (RIS) concept has recently become one of the most powerful policy tools for designing regional development strategies. The RIS concept derived from the former concept of National Innovation System (Freeman, 1987; Lundvall, 1992; Nelson, 1993). The National Innovation System (NIS) is often defined as the complex interaction of individuals, intuitions and organisations to generate new ideas and innovation for creating wealth of nations. In other words, innovation does not always follow a linear path where R&D institutions are producing new ideas and products. Indeed, on the contrary, a national or regional innovation system indicates that within an innovation system we can define their elements, the interactions, the environment and the frontiers which produce economically useful ideas and components (Lundvall, 1992).

The very idea of a regional innovation system is to promote innovation culture, competition and competitiveness for regional economic development. The relationship among the local university, the government and business firms is extremely important in the RIS. Particularly, the local university can play a predominant role in establishing a successful RIS. Universities in general produce, nourish and build skilled human resources for the community by providing tertiary education, training, research facilities, and so on and so forth. Once the critical mass of skilled human resources has been built in any region, the next step is to create proper employment opportunities for the masses. In this regard, establishing a university based Science Park in the local community can play a significant role by creating huge employment opportunities in the form of technology transfer, innovation, spin-offs, R&D activities, business incubators etc. in today's world.

Historically, Philipe Cooke was the earliest scholar to conduct thorough research into the regional innovation system, and published the “Regional Innovations Systems: The role of governances in a globalized world”, at Cardiff university in 1992 to high academic acclaim. One reason why academics attach importance to the regional innovation system is the huge success of the Silicon Valley in USA, and Cheaboll in Korea, where miracles improved the importance of each region in the innovation system.

There are many present day concepts of RIS which address different aspects. According to Storper (1997) innovation is often localised and locally rooted (Storper, 1997; Cooke, 2003; Cooke & Leydesdorff, 2006). This view places specific emphasis on the role of proximity, prevailing sets of rules through the process of knowledge creation and diffusion (Chen, 2008). Cooke (2003) which conceptualised the RIS from social aspect of innovation. Regarding this aspect, he stressed the learning process between different departments within a company, including the department of R&D and University. He also added that bringing innovation from a university classroom to a commercial showroom depends on education, knowledge transfer, R&D linkage, investment in venture capital and ICT communications. Additionally, there are other arguments, such as that put forth by Asheim & Isaksen (2002) who considered the RIS to represent regional clusters which are surrounded by supporting knowledge organisations including universities, research institutes etc. Moreover, Doloreux (2002) argued that the RIS can be conducive to the generation, using the agglomeration concepts and diffusing the knowledge and technology through the interacting interests among formal institutions and other organisations.

In short we can say that the theory and concept of RIS arose in the late 1990s based on theory of agglomeration economies, cluster theory and national innovation system. In a knowledge-based economy (KBE), speed and first mover advantage are central aspects of industrial competition. Therefore, information, technology and network economy become the necessary conditions for regional industrial development. Technology-driven competition is technically difficult whilst links with Higher Education Institute (HEIs) enable local industry to grow early and enter the knowledge-based economies. This fulfills the objective of local and national government to develop local high technology clusters. This in turn makes universities the most productive source of skilled human resources and boosts local science park development by creating regional employment. Very few countries in the world successfully implement this theory and become the frontier of a technology driven development phenomenon. Among them, South Korea, Singapore, Taiwan, Hong Kong, Japan, U.S.A, Germany, U.K, and France are the most notable countries. At this point, the question is, how can university or research institute driven science parks work in a regional innovation system for a particular region or country? Let us consider an example. A local firm is innovating a semiconductor technology and a local university's engineering department partners with this local firm. The partnership is considered an innovative programme, usually administered by the university.

However, the funding for this joint partnership can be ventured by the national research council, the regional industry ministry and the firm itself. The university will advertise accordingly for the doctoral candidate to write his or her thesis on a subject of direct relevance to the firm's innovation needs. As one student completes the doctoral programme there is a chance for him or her to become an employee of the firm as an academic entrepreneur. The programme continues as a cycle to add a new doctoral candidate to solve the next generation of innovation problems. In this way, the university becomes the centre of regional innovation and part of regional economic resilience. Due to the importance of this system, we added a variable called knowledge transfer rate between universities to industry from WCY-2011 database in this chapter. Side by side, we believe that regulatory quality, which encompasses cost of doing business, trade openness, Gov. R&D expenditure and high-tech export, plays a crucial role in regional innovation development, as demonstrated in previous chapter. Hence, regardless of how we divide the innovation system, the foundation and the target remain the same. That is, both of them, NIS and RIS, aim to create more innovation and speed up regional and overall national economic development.

7.1 Research gap in RIS study

A consent to accept RIS as a regional development model seems to have been reached. The question now is how to set in place a benchmarking strategy for the follower countries. Which model or policy should follower regions follow: Silicon Valley model, one of the western European success models, the model of Asian tigers for instance Singapore, Korea or a hybrid Japanese model? A more fundamental question is whether valleys and clusters are one of the panaceas for an accelerated knowledge economy growth pursued by the innovation frontier countries?

Therefore, building an RIS in follower regions is extremely important and by applying non-parametric frontier analysis we can answer the question of how follower regions can learn from frontier countries to become more competitive. In order to solve the above mentioned questions we applied frontier approaches in comparison to production function approaches. This research comprised 6 major sections. Whilst Section 1 provides the introduction and problem statement, Section 2 highlights the theory used, as well as certain concepts of RIS and the distinction between NIS and RIS. Following this, Section 3 explains the variables and descriptive statistics of the sample, Section 4 explains the quantitative methodology for empirical analysis of RIS, and Section 5 discusses the resulting findings, and policy implications. Finally, Section 6 draws the conclusion and summarises the contribution made by this research.

7.2 Theory behind RIS concept

RIS concept is based on three main approaches of sources of innovation:
Firstly, models of idea-driven endogenous economic growth theory by Romer (1986) & Jones (1998). According to them, economic growth depends on the production of the idea-generating sector of the economy. The rate of new ideas production is a function of the stock of knowledge which implies previous generated ideas and the extent of efforts meaning human and financial capital devoted to the ideas-producing portion of the economy (Furman et al., 2002).

Secondly, the cluster-based theory of national industrial competitive advantages by Porter (1990) emphasises the interaction between microeconomic agents such as firms' interaction with the macroeconomic environment and national institutions to affect the overall level of innovation capacity in an economy. Porter identified 4 major drivers in the regional innovation clusters: the quality and specialisation of innovation outputs, the context for firms' strategy and rivalry and the demand conditions.

Finally, The National Innovation System (NIS) approach (Nelson, 1993; Dosi, 1988; Lundvall, 1992; Edquist, 1997) emphasises the notion that national policies and institutional relationships can support the nature and extent of RIS (Lim, 2006). This line of literature highlights the nature of the university system, the extent of intellectual policy protection, the universities and government in R&D performance and funding. Finally, a brief distinction between NIS and RIS is provided in Table 7.1.

Table 7.1: Distinction between NIS and RIS

	NIS	**RIS**
Elements of the system	Mass production economy, process innovation	Knowledge economy, outcome of NIS policy
Inter-firm relationships	Market, emphasis on competition	Network economics, cluster policy
The knowledge infrastructure	Formal R&D laboratories, public R&D funding mostly	University Research, triple helix model using university on top, government funding and focus new product R&D
Institutions of the financial sector	Formal financial sector	Venture capital, informal financial sector
Firm strategy, structure and rivalry	Difficult to start new firms due to government control and formal financial sector	Easy to start new firms and venture capital plays a big role

Source: Lim, 2006, Cooke, 2003

7.3 Variables and sample statistics (Data and variables)

Table 7.2: Potential influencing factors for RIS efficiency and their proxy input-output indicators year 2011

Input factors	Proxy Indicators	Abbreviation	Source of variable
Demographic structure	Population ages 15 to 65 (%of total) as labor force	Lab	World Development Indicators (WDI) 2011
ICT infrastructure	Computer users per 1000	CU	World Development Indicators (WDI) 2011
Financial structure	**Venture Capital availability (IMD survey based on an index 0 to 10)**	VC	World Competitiveness Yearbook (WCY) 2011
Research and Development	R&D expenditure % GDP	RDE	World Development Indicators (WDI) 2011
Education	School enrollment, secondary(%gross)	SE	World Development Indicators (WDI) 2011
Market circumstance	Cost of business start-up procedure (% of GNI per capita)	CBS	World Development Indicators (WDI) 2011
Knowledge transfer**	**Knowledge transfer is highly developed between companies and universities**	KT	World Competitiveness Yearbook (WCY) 2011
Openness	Trade (% of GDP)	TO	Penn Table version 0.7
Natural Resources endowments	Total natural resources rents (% of GDP)	TNR	World Development Indicators (WDI) 2011
Output indicator			
Economically valuable knowledge creation	High-tech export as % total manufacturing exports	HTE	World Development Indicators (WDI) 2011

**** (Updated: MAY 2011, IMD WCY executive survey based on an index from 0 to 10)**

The influencing factors of RIS efficiency (Table 7.2) comprise many elements, including demographic structure, ICT infrastructure, Knowledge Transfer between industry-university, firm-level and Government R&D and innovation activities, economic and market size, trade openness, reliance on natural resources, financial structure, market circumstance, and government level. This conforms to the relevant arguments of the NIS or RIS approach and the New Growth Theory (Balzat & Hanusch, 2004). The firm itself is the most active and important factor in the process of commercialisation of innovation which is represented by the output variable high-tech export as % total manufacturing export. The more firms are involved in R&D and innovation activities, the better the RIS efficiency will be. This is according to the arguments of the Austrian school and Lundvall, with both finding that free interaction of knowledge can create and disseminate economically useful knowledge which develops the wealth of nation (Afzal & Lawrey, 2012a). Schumpeter termed this process creative destruction of the innovation process (ibid).

The age structure of a population also affects the RIS efficiency as well, since young people are thought to be more creative than the old. ICT infrastructure and trade openness would affect the speed and scope of knowledge diffusion and in turn affect RIS efficiency. Furthermore, economic size and degree of openness determine the scale of the domestic and international markets for firms. Indeed, economy of scale and economy of scope can be achieved much more easily in a bigger market, and in turn influence the RIS efficiency indirectly (Balzat & Hanusch, 2004). Moreover, overdependence on natural resources would reduce the innovation capacity and RIS efficiency. In this chapter we added two new variables, namely knowledge transfer between university and industry, with the importance of this variable already explained in the introductory section of this chapter. Another important additional variable for successful RIS was venture capital availability. This variable has enormous significance in promoting high-tech clusters in regional areas. Theoretically speaking, venture capital is provided by an investor to finance a new, growing or troubled business considering the risk factor associated with the venture. Capital is invested in exchange for an equity rather than loan. Venture capital typically looks for new and small businesses with a long term growth potential. Therefore, it plays a vital role in generating finance to back idea driven ventures in a knowledge-based economy.

The 20 emerging and developed countries which we have chosen certainly share a number of characteristics, including high university-industry relationship, skilled labour force and high degree of trade openness. The above mentioned features of RIS are more or less present in our sample economies. Table 7.3 shows the descriptive statistics of our sample year 2011 (cross-section sample). The data are updated from Chapter 6 and we use a more sophisticated benchmarking technique to rank the best practice countries in this chapter.

Table 7.3: Descriptive statistics of the input-output variables

	TO	TNR	SE	KT	RDE	LAB	HTE	VC	CU	CBS
Mean	116.0	3.4644	88.63	4.38	1.98	67.30	21.71	6.38	565.73	9.2950
Median	88.720	2.343	92.23	6.02	1.97	67.0	16.09	6.09	798.91	3.300
Maximum	409.2	13.14	103.2	8.01	3.96	73.58	67.82	8.25	937.8	56.50
Minimum	29.31	0.0000	63.21	3.10	0.08	60.9	1.9	2.50	39.7	0.0
Std. Dev.	106	3.9	11.9	1.6	1.2	3.2	16.2	1.8	372.4	13.4
Observations	20	20	20	20	20	20	20	20	20	20

Source: Author calculation

7.4 Quantitative methodology for empirical analysis of RIS

One of our main objectives was to conduct an empirical analysis of the RIS model. Most of the existing works on RIS models were based on case study and descriptive techniques. Indeed, very few of the studies used parametric or non-parametric methods to analyse the RIS model in macroeconomic study for comparison with different emerging countries or regions (see Appendix D: Table D.1). Therefore, as previously mentioned, this study applied the non-parametric frontier technique to establish the best practice region from our sample. Indeed, Data Envelopment Analysis (DEA), Free Disposable Hull, and the partial frontier analysis technique are normally used under the umbrella of non-parametric analysis. In order to know more about DEA technique, we refer to Afzal & Lawrey (2012b, 2012c, 2012d, 2012e, 2012f). In this particular study, we applied an unconditional partial order-*m* frontier approach. Nonparametric approaches have an advantage as the estimated functions can take almost any form. Additionally, it is often difficult to describe real world observations in a single dependent variable. One of the strengths of the Non parametric technique is that it can consider multiple input-output factors (Brökel, 2008).

7.4.1 Unconditional order-m frontier approaches

We discussed this technique in a non- technical way so that common readers can understand the concept. In contrast with the FDH or DEA approach, the idea behind the order-m approach is that instead of evaluating a region's innovation performance with respect to the performance of all other regions/countries, Cazals et al. (2002) proposed to compare a region with a randomly drawn (sub-) sample of regions. The sub-sample size has to be specified by the researcher and is denoted by *m*, giving the name to the procedure. For instance, in our study we had 20 observations; therefore we were able to choose m= 5, 10, 15, 20 likewise in each step for calculating efficiency of the best practice region. This makes a partial frontier analysis by taking sub-samples instead of all observations. Based on these partial frontiers, the evaluations of the regions/country's' innovation performance were carried out in an identical style to the DEA or FDH approach. Cazals's et al. (2002) order-m performance measure contains most of the characteristics of the FDH or DEA model; in *addition, because the partial frontier is not enveloping all observations, it is less sensitive to outliers and noise in the data*.

7.4.1.1 Technical aspects of unconditional order-m frontier analysis

The main idea of the unconditional *order-m* is simple. For instance, in a multivariate case consider (x_0, y_0) as the inputs and outputs of the unit of interest. $(X_1, Y_1), \ldots, (X_m, Y_m)$ are the inputs and outputs of *m* randomly drawn units that satisfy $X_i \leq x_0$. $\tilde{\lambda}_m(x_0, y_0)$ measures the distance between point y_0 and the order-*m* frontier of $Y_1, \ldots, Y_m$.
The order-m efficiency measure of unit (x_0, y_0) is defined as:

$$\lambda_m(x_0, y_0) = E[\tilde{\lambda}_m(x_0, y_0) \updownarrow X \leq x_0]$$

For a general understanding of the conditional and unconditional *order-m* approach see Simar & Wilson (2006). For more technical details see Daraio & Simar (2007) for robust nonparametric frontier techniques.

7.5 Results and discussion

The result presented in Figures 7.1, 7.2, 7.3 and 7.4 are returned from the software used in this study, namely FEAR (Frontier Efficiency Analysis with R) described by a Paul W. Wilson (2008). We selected 20 emerging and developed knowledge-based economies in order to establish the best practice country/region (see Appendix Table B.3). We attempted to demonstrate how empirical analysis can be conducted in the field of RIS. The obtained performance measure represented a Monte-Carlo rough calculation with 200 imitations (Cazals et al., 2002). Researchers have shown that in numerous applications, research results are not affected by particular choices of *m*, as long as the value of *m* are less than the sample size, *n* (Simar and Wilson, 2006). For information on how to calculate order-m efficiency, see package 'FEAR' by Paul W. Wilson (2008), p-27.

The first spider diagram (Figure 7.1) represents the order-m=5 partial frontier results, which show that South Korea, Malaysia, Switzerland and Singapore were the best practice region in 2011 compared to other sample countries. The second diagram (Figure 7.2) exhibits the consecutive results of Fig: 01 in the case of m=10. In Figure 7.3 China along with Asian 3 appeared as best practice regions in the case of m=15. Finally, Figure 7.4 shows the full frontier analysis, with South Korea, Malaysia and Singapore appearing to be the best practice frontier regions in the RIS context. These 3 ASEAN (Association of South East Asian Countries) countries are consistently efficient in different partial frontier analysis (m=5, 10, 15 and 20). This implies that follower regions or inefficient regions (efficiency score less than 1) can learn the policy implications from them and apply these according to the need of their economy. Our study briefly discussed South Korea, Malaysia and Singapore's RIS policies in the discussion section. We attempted to answer the question of how these countries become best practice countries and achieve remarkable success in RIS using potential RIS input-output factors.

Figure 7.1: m=5 Efficiency Results

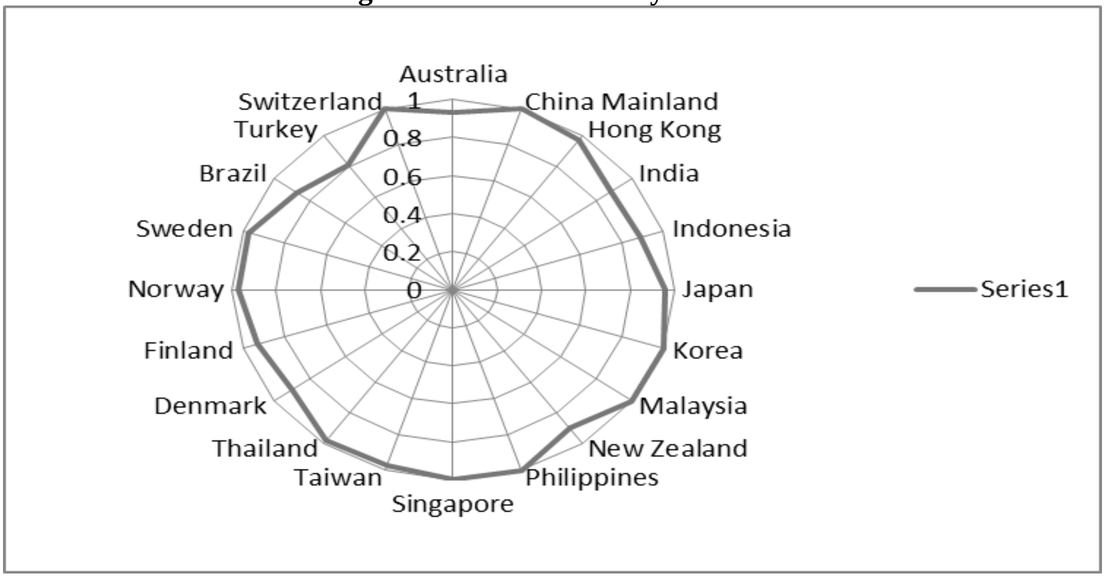


Figure 7.2: m=10 Efficiency Results

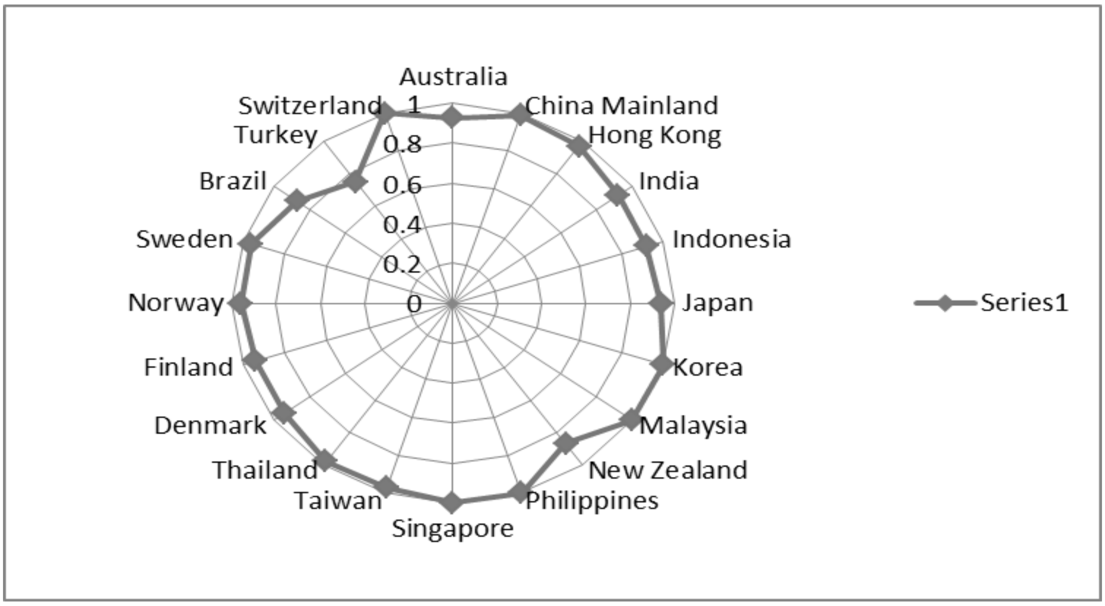


Figure 7.3: m=15 Efficiency Results

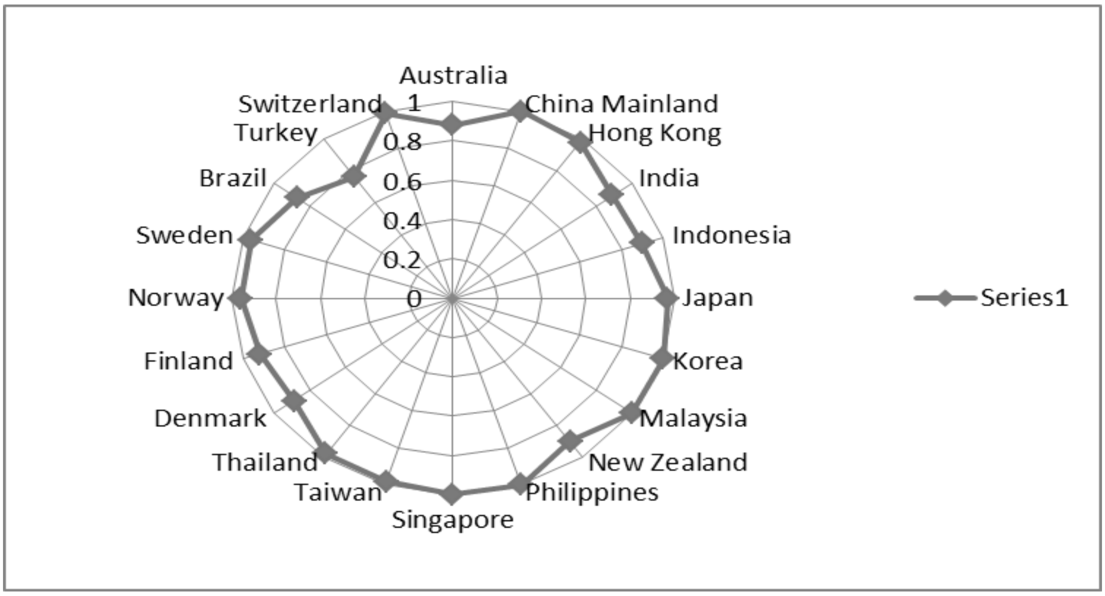
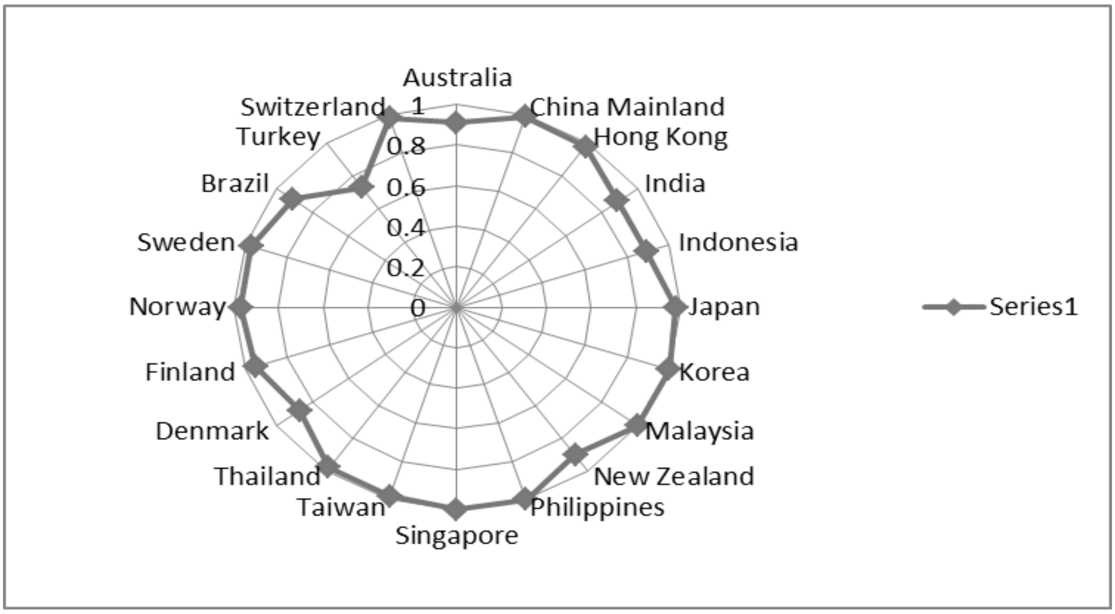


Figure 7.4: m=20 Efficiency Results



7.6 Policy discussion

At the beginning of this chapter, we stated the research problems, namely which model or policy should follower regions follow? We were also seeking to answer a more fundamental question, namely whether valleys and clusters represent one of the factors of a knowledge economy for a nation and a region? From our empirical results we uncovered three best practice countries, namely South Korea, Singapore and Malaysia, compared to other sample DMUs (countries) in the RIS framework. Therefore, follower regions can now follow or emulate one of the RIS policies of frontier countries. We shall discuss the key RIS policies adopted by these frontier countries and try to provide an answer as to whether science park, high-tech clusters or regions are the answer to a successful RIS for a nation. We start with South Korea; in order to boost the regional economy and enhance national competitiveness South Korea has established a number of techno parks in the country.

The main mission of establishing a science or Techno Park is to transform the industry structure; attracting foreign high-techs, creating more jobs, accelerating technological innovation through networking industry, college, university, research centres and local government collaboration and increase Korean global competitiveness by regionally specialised high technology. South Korea has high speed internet service, high number of computer users per 1000 population, low cost of doing business, availability of venture capital and well-structured government regulatory policy (Seo, 2006; Nelson, 1993). By using these resources, South Korea has established 16 high-tech parks within the period spanning 1998-2005 periods and also formed a business cluster named *Cheaboll*. This *Cheaboll* grouped followed a Japanese *Keiretsu cluster* model where the government deliberately facilitates the business group in order to promote high-tech export (Nelson, 1993). During this short period of time, Korea has achieved remarkable growth of high-tech export (42.9% high-tech export as total manufacturing share, WDI-2011).

The establishment of Techno-parks not only increases the high-tech export, but also establishes the incubation of business, increases research and development, equipment utilisation, pilot production, information sharing and education and training. During the period spanning 1998-2003, the Korean government first took the initiative to build an institutional network between the university, industry and local government and to start business incubation of high-tech firms. In contrast, during the second stage after 2003 until now, the government placed emphasis on regional development by decentralising Techno-parks to provide a balanced national development. Due to this, the South Korean skilled labour force, as well as its financial infrastructure, ICT network, and secondary and tertiary education enrolment have experienced a remarkable upsurge (Nelson, 1993).

In line with economic geography theory, Singapore has used its small geographical location remarkably well in order to drive technological development and to become a regional hub of ICT (Monroe, 2006). In 1980, to emulate the success of science and high-tech clusters like Silicon Valley and Route 128, the government established the Singapore Science Park (SSP). The SSP has now become an integrated part of the technological policy which supports Singapore's economic growth strategy. The primary reason for developing the SSP was to provide a conducive environment and facilities to attract MNCs (Monroe, 2006). In addition, the SSP was perceived to serve as an incubator for the growth of high-tech industries, skilled human resources development, good financial structure, availability of bank credit for new ventures, employment generation and ensuring of overall high-tech driven growth. Venture capital is another important component (from our sample variable) for successful RIS in Singapore. The growth of new high-tech or medium tech manufacturing firms depends on venture capital availability in Singapore. In reality, venture capital follows the innovation initiative (Lim, 2006).

In 2011, Singapore scored 6.05, making it the highest scoring Asia-Pacific region in terms of venture capital which is easily available for business index (Updated: MAY 2011, IMD WCY executive survey based on an index from 0 to 10).

Unlike Singapore, Malaysia, this is one of the best practice regions judging by our calculation, developed and strengthened their country around a 2020 vision. This has also served as the nation's roadmap for economic development. Under this roadmap Malaysia has established a number of key institutions which are related to ICT growth and high-tech clusters. The Malaysian Development Corporation (MDC) is one of these key institutions whilst they also built the Multimedia Super Corridor (MSC), the country's most prominent science and high-tech cluster. The MSC is Malaysia's flagship science and high-tech research project. It encompasses Kuala Lumpur and 5 other key infrastructural projects which are PETRONAS Twin Tower, Putrajaya, Cyberjaya- an intelligent research and development city, Technology Park Malaysia and Kuala Lumpur tower. By establishing science and techno parks in different regional locations of Malaysia, the government wants to raise the level of technological sophistication of local industries, promote foreign investments, and finally accelerate the transition from a labour intensive to a knowledge-based economy (Nelson, 1993).

Hence, this discussion indicated that all three best practice countries from our calculation have bought into theories from economic geography, NIS and cluster approach that location does matter in the RIS context. In other words, *valleys and clusters are one of the panaceas for a regional development.* These countries are following policy prescription to develop strong regional and national innovation systems by placing emphasis on Techno parks, and high-tech clusters. In addition, these parks are leading the overall economic development by creating employment opportunities, increasing skilled human resources, widening the market for high-tech products by high degree of trade openness, maintaining good financial structure and spurring ICT driven growth. Hence, the best practice countries such as South Korea, Singapore and Malaysia achieved a rapid growth in innovation infrastructure, which is mainly due to high capital accumulation in the early stage of economic development and well educated labour forces. Moreover, it was argued that South Korea, Singapore and Malaysia all grew fast in the national or regional innovation system because their policy makers have managed a sound macroeconomic stability in the country during this transition period (Rodrik, Grossman & Norman, 1995; Rastin, 2003; Booth, 1999; Afzal & Manni, 2013). Initially, South Korea, Singapore and Malaysia followed the policies of frontier regions in RIS, including Silicon Valley, Route 128 or Japanese *Keiretsu* cluster models to build a similar kind of strategy in their respective countries. Hence, our methodology and policy discussion also indicates that there is a need of frontier analysis for successful RIS policy implication in the follower nations.

7.7 Conclusion

In this study, the policy concepts of regional innovation systems have been introduced, defined and empirically analysed. The new world economic trends emphasise the regional economic development to ensure a balance of economic growth in the country. In applying the concept and empirical analysis to 20 developed and emerging knowledge-based nations, it is useful to investigate variable specific regional innovation systems. By looking at such variables or dimensions as education enrolment, knowledge transfer between university to industry, trade openness, ICT users, R&D expenditure, and high-tech export growth, it is possible to more strongly detect the importance and performance of regional innovation systems. Our research attempted to answer the research question regarding which model or policy follower regions should follow? We also sought to answer the more fundamental question of whether valleys and clusters are one of the panaceas for a nation and a region? By addressing this question, the present chapter contributed to the existing literature in two ways.

First, we applied a robust non-parametric unconditional *order-m* partial frontier approach to identify best practice nations in the RIS context. It was argued in the study that a partial frontier such as the *order-m* approach is more applicable for analysing the regional innovation system framework than the traditional FDH (Free Disposable Hull) approach. This is due to the advantage of overcoming outliers or extreme points from the sample. We apply a cross-section approach and used the latest dataset from World Development Indicators-2011, World Competitiveness Yearbook-2011 and Penn world table for our analysis. We have found that South Korea, Singapore and Malaysia are the best practice countries among most of the emerging and developed knowledge-based countries from our sample. Whilst conducting a policy analysis of these 3 countries, our study reveals that location is important when it comes to a successful regional innovation system.

Our findings indicate that investing in Techno-parks, Science city or high-tech clusters certainly generates more employment opportunities, builds a skilled labour force, well-structured financial systems, encourages venture capital in regional locations, and thus ensures a balanced economic development. By combining the strong policy points of each of the best practice nations (South Korea, Malaysia and Singapore), policy-makers of follower regions could produce an interesting, profitable and flexible vision which can fit into their economic system in order to achieve sustainable knowledge based economic growth.

Hence, in order to transform ides from classroom education to practical policy implication, we believe, it is essential to investigate the regional innovation system and its applications for future knowledge based generations. In future research, we recommend conditional order-m and α (alpha) frontier analysis to observe the comparison of our sample regions with regions adopting similar values in an external factor *z, e.g. the externality variable.* In order to achieve this (conditional order-m analysis), the *m* observations are not drawn randomly but are instead conditional on the external factors. We believe it is worth looking into how results vary when we put condition on the *selection of m* in order-m frontier analysis.

CHAPTER 8: CONCLUSION AND POLICY IMPLICATION

8.0 Policy implications

In order to transfer from the catching up stage to the cutting edge growth process, selected ASEAN and emerging knowledge economies can follow certain policy implications. This discussion reflects the overall policy analysis of the present thesis.

Firstly, emerging knowledge-based countries should emphasise that in order to create output or wealth of the nations, the factors of each knowledge dimension (acquisition, production, distribution and utilisation) in the KBE must be produced and organised efficiently.

Secondly, improving the government's regulatory quality through proper incentives is the key to a national and regional innovation system. For instance, 'the business culture and institutions of the United States and South Korea are good at connecting innovators with business people and venture capitalists. In the United States, potential innovators know that if they come up with a good idea, that idea has a good chance of making it to the market. The incentive to discover new ideas is correspondingly strong' (Cowen & Tabarrok, 2009, p: 525; Rastin, 2003; Rodrik, Grossman & Norman, 1995; Booth, 1999).

Thirdly, in pursuit of a large market size for high-tech goods; theoretically larger markets mean increased incentives to invest in research and development, with more new drugs, computer chips, software and ICT goods subsequently produced. For instance, As India, China, and other countries including the United States become wealthier, companies in South Korea and Singapore increase their worldwide R&D investments and sales accordingly.

Finally, according to the models of Helpman & Grossman (1991) and Aghion & Howitt (1992) products improve along with quality ladders. Every new product is highly substitutable for a similar product of lower quality, but less substitutable for other products. Hence, the future challenges for ASEAN knowledge economies depend on their quality management of innovative high-tech products. If they can win the quality improvement battle, the economy will continue to grow and create wealth for the society. In addition, one other challenge for the ASEAN region is to increase product variety from R&D. Theoretically speaking, more product variety raises the economy's production potential as it allows for a given capital stock to be spread over a larger number of uses, each of which exhibits diminishing returns. Thus, increased product variety is what sustains growth for the future. New varieties, that is, new innovations themselves result from R&D investment by researchers, entrepreneurs who are motivated by the prospect of monopoly rents if they successfully innovate (Aghion & Howitt, 1992). For instance, our DEA analysis suggested that the Philippines' economy is doing very well in high-tech export as a % of total manufacture exports.

However, the truth is that the bulk of the Philippines' exports is in electronics goods, and specifically semiconductors. Semiconductors usually fall under the high-tech product classification, which covers the major share of the Philippines' manufacturing export. Therefore, economists have described the growth of the Philippines' domestic economy as narrow, shallow and hollow, as it has been propelled by a limited number of sectors and concentrated in urban areas. This is a challenge for the Philippines and other ASEAN members if they want to transfer their economy to a cutting edge or knowledge-based economy (Vera & Lee, 2003).

Putting all this together, economic growth might be faster and sustainable in the future than it has been in the past for the ASEAN region. There are more scientists, engineers and high-tech goods produced in the ASEAN today than ever before. The incentives to invest in R&D are also increasing because of the larger market size due to globalisation and the rise of wealth in developing countries such as China and India. Better institutions and secure property rights are now widespread throughout the world. Hence in the end, we can say that the future of knowledge economic growth in the South East Asian region will accelerate and be sustained if they can successfully move from the Catching Up to the Cutting edge era.

8.1 Contribution and findings from the study

This study has attempted to investigate the knowledge-based economy frameworks, measurement techniques and policy analysis. The key contributions of the study include answering the following research questions:

Research questions:

1. To examine whether existing frameworks can explain KBE?

Findings:

The evidence from Chapters 2 and 3 suggests that there are shortcomings with existing WBI, OECD, ABS, APEC KBE frameworks in the use of a universal approach across countries in different regions, at different stages of development and with different institutional, social and economic characteristics. Not only may this approach be theoretically questionable, but it may simply be impossible given the lack of consistent data in many developing countries. The more pragmatic approach used here is to see what data is available under the four WBI pillars and to attempt to make some policy recommendations based on the picture which emerges. We consider a resource-based country - Brunei Darussalam - as a case study in Chapter 3 so as to demonstrate the shortcoming of the existing KBE frameworks.

Chapter 2 of this study shows that the knowledge-based economy is not an entirely new concept, but rather a perception which prevailed thousands of years ago. What we have seen is economists attempting to articulate this phenomenon into a sophisticated model and naming them as the difference between Ricardian diminishing return vs. neo classical endogenous model of increasing return; Scarcity of physical resources vs. abundance of ideas; exogenous vs. endogenous technological progress etc. This historical approach to the evolution of the KBE concept is missing in the existing frameworks; something which we believe to be important when it comes to understanding the knowledge-based growth phenomenon in creating wealth of nations.

Research questions:

2. Is there any need to include or omit new variables in the existing frameworks, or

3. Is there a need for a new conceptual framework of KBE to compare the issue of measurement technique of different KBE indicators for selected South East Asian countries?

Findings:

Chapters 3, 4 and 5 empirically demonstrate the ranking of KBE variables for our sample countries over the years according to their importance. A review is also proposed of KBE indicators whilst a policy-focused KBE framework is drawn and the DEA cross-section and time series methods are applied to show the technical and scale efficiency of the selected ASEAN countries in our referred time period. The results show that Indonesia in the knowledge acquisition dimension, Singapore, South Korea and Thailand in the knowledge production dimension, Singapore in the knowledge distribution dimension and the Philippines and South Korea in the knowledge utilisation dimension were the most productive and 100% efficient countries in one referred year or the other. These approaches overcome the problem of measurement and comparison issues among neighbour countries in light of the knowledge-based economy. We also highlight the shortcomings of existing KBE frameworks in addressing the scale, establishing the most productive scale size, searching the appropriate peers or best practice countries to emulate, productivity comparison with neighbouring countries more systematically. We demonstrate the possible solutions of these shortcomings with proper methodologies and theoretical backgrounds while answering the research questions below.

Research questions:

4. What are the potential input factors of the national and regional innovation system (in the case of ASEAN and emerging countries)?
5. What are the potential output factors of the national and regional innovation system?
6. How can the efficiency of the national and regional innovation system be evaluated?
7. What innovation policies lead to best performance in countries?

Findings:

In Chapters 6 and 7, the policy concepts of national and regional innovation systems are introduced, defined and empirically investigated. The new world economic trend shifts towards regional economic development. In applying the concept and empirical analysis to twenty developed and emerging knowledge-based nations, it was useful to note how the potential statistical indicator specific regional and national innovation systems may look. From our empirical results we uncovered three best practice countries, namely South Korea, Singapore and Malaysia, compared to other sample DMUs (countries) in the NIS and RIS frameworks. By observing variables or dimensions such as education enrolment, knowledge transfer between university to industry, trade openness, ICT users, R&D expenditure, and high-tech export growth, it is possible to more effectively detect the importance and performance of regional and national innovation systems. In order to transform ides from classroom education to practical policy implication, we argue in these chapters that it is essential to investigate the national and regional innovation system and its applications for future knowledge based generations.

8.2 Limitation of the research

There are certain limitations to this research; limitations which have already been highlighted in each chapter. However, here is the synopsis of the study's main limitations:

With regard to Chapters 1 and 2, the study failed to find adequate literature on knowledge economy frameworks. A very small number of studies had reviewed existing KBE frameworks, measurement issues and policy implications.

In Chapter 3, this study also failed to find sufficient data with which to investigate important KBE input-output variables for a long time series study.

In Chapters 4 and 5, the study did not consider a large sample size both in cross-section and time series analysis due to data unavailability for all of the sample countries.

In Chapters 6 and 7, the study did not focus on conditional order-alpha and order-m analysis. Usually, conditional order-alpha or order-m analysis considers a specific variable, such as environmental or exogenous variables which can affect the DMU's efficiency performance. This research considered only unconditional order alpha and order-m analysis to demonstrate the bias corrected benchmarking technique.

8.3 Future direction

Firstly, future research can be directed to a more in depth case study approach to investigating country specific KBE framework analysis.

Secondly, future researcher can consider a large sample size so as to investigate the DEA cross section and window analysis to measure efficiency, scale economics and productivity performance.

Thirdly, future researcher can apply parametric frontier models such as the stochastic frontier analysis (SFA) in efficiency analysis using KBE input-output variables and to investigate the efficiency differences between SFA and DEA models.

Fourthly, a more sophisticated model such as the conditional order-alpha or order-m can be used to rank the best practice countries and investigate the effect of exogenous variables on efficiency performance.

Finally, on occasions it is useful to apply qualitative investigation in order to establish the root cause of efficiency variation in national and regional innovation systems in a cross-country study.

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Appendix A

Table A.1: OECD, APEC and WBI Knowledge Economy Pillars and Indicators

OECD	APEC	WBI
1. Knowledge-Based Economy 1.1 Knowledge Investment (education, R&D and software) as % of GDP 1.2 Education of the adult population as % of the population aged 25-64 1.3 R&D expenditure as a percentage of GDP 1.4 Basic research expenditure as a percentage of GDP 1.5 Expenditure of Business R&D in domestic product of industry 1.6 Expenditure of Business R&D in manufacturing 1.7 Share of services in R&D expenditure 1.8 Expenditure on innovation as a share of total sales 1.9 Investment in venture capital as a percentage of GDP	1. Business Environment 1.1 Knowledge based Industries as % of GDP 1.2 Services Exports as of GDP 1.3 High-Tech Exports as of GDP 1.4 Foreign Direct Investment inward flow as % of GDP 1.5 Government transparency rating by World Competitiveness Yearbook 1.6 Financial transparency rating by World Competitiveness Yearbook 1.7 Competition policy rating by World Competitiveness Yearbook 1.8 Openness rating by World Competitiveness Yearbook	1. Performance 1.1 Average annual GDP growth (%) 1.2 Human Development Index
2.Information and Communication Technology 2.1 ICT spending as % of GDP 2.2 PC penetration in households 2.3 Number of internet host per 1000 inhabitants 2.4 Percentage share of ICT industries in GDP 2.5 Share of ICT in patents granted by USPTO	2. ICT Infrastructure 2.1 Number of mobile telephones in use per 1000 inhabitants 2.2 Number of telephone mainlines in use per 1000 inhabitants 2.3 Number of computers per 1000 inhabitants 2.4 Number of internet users as % of population 2.5 Internet hosts per 10000 2.6 Expected e-commerce Revenues, M$US	2. Economic Incentive and Institutional Regime 2.1 Tariff and non-tariff barriers 2.2 Regulatory Quality 2.3 Rule of Law
3. Science and Technology Policies	3. Innovation System 3.1 Scientists Engineers in R&D	3. Education and Human Resources

3.1 Publicly funded R&D as % of GDP 3.2 Government R&D expenditure on health-defense-environment 3.3 Government R&D expenditure in total R&D expenditure 3.4 Business R&D expenditure in total R&D expenditure 3.5 Share of Government-Business R&D expenditure financed together 3.6 Tax subsidies rate for R&D	per million of the population 3.2 Full-time researchers per million of the population 3.3 Gross Expenditure on R&D (% of GDP) 3.4 Business Expenditure on R&D (% of GDP) 3.5 US Patents per annum 3.6 The number of technological cooperation among companies 3.7 The number of technological cooperation between company-university	3.1 Adult Literacy rate (%age 15 and above) 3.2 Secondary Enrolment 3.3 Tertiary Enrolment
4. <u>Globalization</u> 4.1 Share of foreign affiliates in R&D 4.2 Share of foreign and domestic ownership in total inventions 4.3 Number of international technological alliances 4.4 Percentage of scientific publications with a foreign co-author 4.5 Percentage of patents with a foreign co-investor	4. <u>Human Resource Development</u> 4.1 Secondary enrolment (% of age group) 4.2 Natural Sciences Graduates per annum 4.3 Knowledge Workers (% of labor force) 4.4 Newspaper (per 1000 inhabitants) 4.5 Human Development Index	4. <u>Innovation System</u> 4.1 Researchers in R-D, per million populations 4.2 Patent Applications granted by the USPTO, per million populations 4.3 Scientific and technical journal articles, per million populations
5. <u>Output and Impact</u> 5.1 Scientific publications per 100 000 population 5.2 Share of countries in total EPO patent application 5.3 Share of firm creating any innovative output 5.4 GDP per employed person 5.5 Share of knowledge-based industries in total value added 5.6 Share medium-high technology industries in manufacturing export 5.7 Technology balance of payments as a percentage of		5. <u>Information Infrastructure</u> 5.1 Telephones per 1000 persons, (telephone mainlines + mobile phones) 5.2 Computers per 1000 persons 5.3 Internet Users per 10000 persons

GDP		

Source: OECD, (1999), "The Knowledge-Based Economy: A Set of Facts and Figures", Paris, APEC, (2000), "Towards Knowledge-Based Economies in APEC", APEC Economic Committee, World Bank Database, The Knowledge Assessment Methodology (KAM), website (www.worldbank.org/kam) (Cited in Karahan, 2011)

Table A.2: KBE frameworks and a proposed policy-focused KBE framework

	Knowledge acquisition	**Knowledge production**	**Knowledge distribution**	**Knowledge utilization**
Input	1.Oppenness (Exports + imports)/GDP 2. FDI inward flows as % GDP	1.Scientific R & D expenditure as % GDP 2.Researchers per 1000 population 3.Inteclactual Property Rights (IPR)	1.Education expenditure as % GDP 2. Net enrolment ratio at secondary school 3.ICT spending as % GDP	1.Technological R&D expenditure as % of GDP 2.Business R&D expenditure in total R&D expenditure 3.Knowledge transfer rate 4.FDI inflows %GDP
Output	1.Competitiveness 2.HDI 3.Real GDP growth	Scientific publications per 1000 population	1.Tertiary education per 1,000 population. 2.PC penetration per 1,000 population 3.Internet host per 1,000 population	1.Share of patent applications to EPO total. 2.Exports of ICT products as % of total. 3.Production of High- Tech sector as % of total GDP

A.3: Advantages of using MPI

Usually for econometric analysis researchers tends to use growth accounting method where a Cobb-Douglas production function regress to find the productivity changes across the nations. However, due to its limitation, we apply DEA MPI method which can capture robust characteristics of productivity changes. In Table A.3 our study reveals the distinction between econometric and non-parametric MPI methods.

Table A.3: The comparison between Econometric and DEA MPI productivity analysis methods

	Econometric	**DEA MPI**
Characteristic	Parametric method	Non- Parametric method
Efficiency measurement	Technical change and TFP change in terms of significant variables. Does not reveal scale, technological changes in the productivity.	Technical efficiency, scale elasticity, scale efficiency, allocative efficiencies, technical change and TFP change, Technological efficiencies changes
Strengths	1. It does not assume that all firms are efficient in advance 2. Regression analysis makes accommodation for statistical noise such as random variables of weather, luck, machine breakdown and other events beyond the control of firms and measure error. 3. It is capable to hypothesis test 5. It estimates based on average not as best practice frontiers 6. Econometric method are not unit invariant.	1. It does not assume that all firms are efficient in advance. 2. It could handle with efficiency measurement of multiple outputs but weak in measuring noise in the analysis. 3. It does not need to price information available. 4. It does not need to assume function type and distribution type 5. While sample size is small, it is compared with relative efficiency 6. Both the CCR and BCC models have nature of unit invariance which leads MPI unit invariant too.
Weakness	1. It needs to assume functional form and distribution type in advance 2. It needs enough samples to avoid lack of degree freedom 3. The assumed distribution type is sensitive to assessing efficiency scores	1. It does not make accommodation for statistical noise such as measurement error 2. It is not capable to hypothesis test. 3. When the newly added DMU is an outlier, it could affect the efficiency measurement.
Application	It has applied to measure productivity performance of organizations in terms of single output or dependent variable. Econometric regression or growth accounting method hardly can incorporate more than one	It has applied to assess productivity performance of non-profit/profit organizations or branches of firm with multiple input and output which gives MPI superiority over regression analysis.

	dependent variable.	

Source: Coelli *et. al.* (1996)

APPENDIX B

Table B.1: World Bank Knowledge Economy Indicators (Basic Scorecard)

1. Performance
1.1 Average annual GDP growth (%)
1.2 Human Development Index
2. Economic Incentive and Institutional Regime
2.1 Tariff and non-tariff barriers
2.2 Regulatory Quality
2.3 Rule of Law
3. Education and Human Resources
3.1 Adult Literacy rate (%age 15 and above)
3.2 Secondary Enrolment
3.3 Tertiary Enrolment
4. Innovation System
4.1 Researchers in R-D, per million populations
4.2 Patent Applications granted by the USPTO, per million populations
4.3 Scientific and technical journal articles, per million populations
5. Information Infrastructure
5.1 Telephones per 1000 persons, (telephone mainlines + mobile phones)
5.2 Computers per 1000 persons
5.3 Internet Users per 10000 persons

Source: World Bank Database, The Knowledge Assessment Methodology (KAM), website (www.worldbank.org/kam)

Table B.2: Data supporting the most recent performance of China and India

Average Annual GDP growth (most recent) is the average annual GDP growth for the period 1998-2002.

Variable	China actual / normalized	India actual / normalized
Average Annual GDP growth (%)	7.60 / 9.67	5.40 / 8.68
Human Development Index	0.72 / 3.58	0.59 / 2.00
Tariff & nontariff barriers	2.00 / 0.00	2.00 / 0.00
Regulatory Quality	-0.41 / 2.89	-0.34 / 3.31
Rule of Law	-0.22 / 4.38	0.07 / 5.04
Researchers in R&D / mil. pop.	583.88 / 4.67	157.38 / 2.39
Scientific and technical journal articles / mil. pop.	9.31 / 4.00	9.23 / 3.92
Patent applications granted by the USPTO / mil pop.	0.21 / 4.11	0.17 / 3.55
Adult literacy rate (% age 15 and above)	84.80 / 3.47	58.00 / 1.24
Secondary enrollment	62.82 / 3.39	48.70 / 2.23
Tertiary enrollment	7.45 / 2.25	10.49 / 2.92
Telephones per 1,000 (mainlines + mobiles)	327.80 / 4.88	52.00 / 1.74
Computers per 1,000	19.00 / 3.30	5.80 / 1.39
Internet users per 10,000	460.09 / 4.88	159.14 / 2.73

Table B.3: Efficiency scores for order-*m from* FEAR software

Country	Order m=05	Order m=10	Order m=15	Order m=20
Australia	0.93	0.9283	0.88	0.91
China Mainland	1	0.99	1	0.99
Hong Kong	0.97	0.97	0.98	0.98
India	0.88	0.92	0.89	0.89
Indonesia	0.89	0.92	0.9	0.89
Japan	0.96	0.94	0.97	0.98
South Korea	**1**	**1**	**1**	**1**
Malaysia	**1**	**1**	**1**	**1**
New Zealand	0.9	0.87	0.9	0.9
Philippines	0.9	0.98	0.9	0.9
Singapore	**1**	**1**	**1**	**1**
Taiwan	0.97	0.97	0.98	0.98

Thailand	0.98	0.98	0.98	0.98
Denmark	0.9	0.94	0.89	0.87
Finland	0.93	0.94	0.92	0.95
Norway	0.97	0.96	0.96	0.97
Sweden	0.97	0.96	0.96	0.97
Brazil	0.87	0.87	0.87	0.91
Turkey	0.81	0.75	0.76	0.73
Switzerland	1	1	0.99	0.98

Source: Authors' calculation

Table B.4: Key literature on NISs

Authors	**Study countries**	**Inputs and outputs used in NIS model**	**Key results**	**Shortcomings**
Cai, Y (2011)	Brazil, Russia, India, China and South Africa along with 17 countries	***Input:*** R&D expenditure as % of GDP, total R&D personnel; ***Output:*** Patents per 1000 population, scientific articles per 1000 pop. and high-tech exports as % of total manufacturing exports	Russia, China and India have relatively high efficiency scores while Brazil and South Africa rank at the bottom	Use DEA and panel regression model without correcting the bias or outlier problem in the sample.
Balzat & Hanusch (2004)	Theoretical concept	Explain DEA method for performance analysis	Suggestion in favour of using DEA method	There is no empirical analysis to support the suggestion
Pires,O.J., Garcia, F (2012)	75 countries	SFA productivity analysis	Productivity of nations depends on allocative and scale efficiency	SFA is a parametric model and often require specific probability distribution and functional form, DEA does not require any of these
Singh, L (2006)	Selected Asian countries	Descriptive analysis. Inputs: R&D expenditure as % GDP, researchers per million pop. Output: high-tech exports,	Innovation capacity depends on the combination of these input-	Again no robust empirical analysis

		scientific articles per 1000 population, UNCTAD innovation index	output variables	
Sanders, L.J.W.M; Lamoen, V.R.C.R; Bos, B.W.J (2011)	Netherlands	SFA method, R&D input and output at firm level analysis	Innovation follows Schumpeter mark II hypothesis and scale efficiency	SFA can't take multiple dependent variables while DEA can. No macro level analysis in the study as NIS is highly depend on central government policy
Freeman, C (1987)	Theoretical perspective	Theory and history of NIS concept	NIS definition	No empirical analysis to support the current trends of NIS
Nelson, R.R. (1993)	Theory and Concept of NIS for U.S.A, Canada, Germany, Britain, Netherlands, South Korea, Brazil, Taiwan, Japan, Australia etc	Qualitative argument of NIS concept	Features of NIS of different countries	No empirical analysis to support the recent trends of NIS
Mathews, A.J.; Hu, C.M. (2005)	Selected East Asian countries	Descriptive and regression analysis, R&D expenditure as major input and patents considered as major output of innovation	Late comer countries have advantages to catch up with the developed countries	Parametric analysis often depend on specific functional form and need specific sample distribution, in contrast non parametric such as DEA does not require those
Lundvall, (1992)	Theoretical perspective	Theory and history of NIS concept	NIS definition	
Tangchitpiboon, T; Chairatana, A.P.; Intarakumnerd, P. (2001)	Thailand	Descriptive analysis	Thailand should focus on factors contributing to the long-running perpetuation of weak and	No robust empirical analysis

			fragmented NIS	
Feinson, S. (2001)	Theoretical perspective	Theory and history of NIS concept	NIS definition	
Monroe, T (2006)	Singapore and Malaysia	Descriptive analysis	Connect with creative talent wherever it resides and build relationships that enable all parties to innovate more rapidly and to get better faster by working with each other	No robust empirical analysis
T.-W. Pan, S.-W. Hung & W.-M. Lu (2010).	33 Asian and European countries	DEA, bilateral DEA model	The overall technical inefficiencies of the NIS activities in these countries are primarily due to the pure technical inefficiencies rather than the scale inefficiencies	There is no correction of bias or outliers in the sample.

APPENDIX - C

Indicators measuring knowledge inputs

Table C.1: Openness at 2005 constant prices (% of GDP) in selected ASEAN economies

Economy	1995	2000	2005	2010
Indonesia	55	53.99	61.81	56.98
Malaysia	183.91	199.86	211.26	199.28
Singapore	326.4	335.94	429.76	410.13
Philippines	104.59	97.65	110.83	88.79
Thailand	118.6	139.05	148.82	135.67

Source: Penn World Table Version 7.0

Table C.2: Legal & Regulatory framework

Economy	1995	2000	2005	2010
Indonesia	4.10	2.90	3.07	4.56
Malaysia	5.86	6.49	5.98	6.93
Singapore	7.85	8.82	7.52	7.67
Philippines	4.30	4.49	3.60	3.18
Thailand	4.20	5.40	5.55	4.09

Source: IMD WCY executive survey based on an index from 0 to 10, May 2011

Table C.3: Research and Development expenditure (% of GDP)

Economy	1995	2000	2005	2010
Indonesia	0.09	0.07	0.05	0.08
Malaysia	0.27	0.47	0.60	0.88
Singapore	1.16	1.85	2.19	3.21
Philippines	0.13	0.15	0.12	0.12
Thailand	0.12	0.25	0.23	0.24

Source: WDI-2010, WCY-2011, ASEAN statistical department, Jakarta

Table C.4 Transparency

Economy	1995	2000	2005	2010
Indonesia	4.13	5.0	2.68	4.58
Malaysia	6.10	6.37	5.24	5.98
Singapore	6.81	8.36	6.95	7.59
Philippines	4.10	3.26	2.91	1.65
Thailand	4.39	4.35	4.68	3.70

Source: WDI-2010, WCY-2011, ASEAN statistical department, Jakarta

Table C.5 Foreign direct investment, net inflows (% of GDP)

Economy	1995	2000	2005	2010
Indonesia	2.15	-2.75	2.91	1.98
Malaysia	4.70	4.0	2.87	2.90
Singapore	13.68	17.77	12.38	9.32
Philippines	1.99	2.95	1.87	1.22
Thailand	1.23	2.74	4.56	1.9

Source: WDI-2010, ASEAN Secretariat - ASEAN FDI Database as of 30 June 2010.

Table C.6 Total Education Expenditure % of GDP

Economy	1995	2000	2005	2010
Indonesia	1.33	0.60	1.06	1.51
Malaysia	4.77	3.95	5.13	6.51
Singapore	3.08	3.61	2.91	3.26
Philippines	3.23	2.90	2.48	2.87
Thailand	3.58	4.50	3.70	3.99

Source: WDI-2010, WCY-2011, ASEAN statistical department, Jakarta

Table C.7 Secondary School Enrolment % of total

Economy	1995	2000	2005	2010
Indonesia	56.6	49.70	59.23	68.98
Malaysia	63.80	64.83	68.73	70.10
Singapore	76.00	92.00	94.00	95.97
Philippines	76.00	50.10	59.01	62.00
Thailand	53.19	69.70	73.56	72.06

Source: WDI-2010, WCY-2011, ASEAN statistical department, Jakarta

Table C.8 Knowledge Transfer (Knowledge transfer is highly developed between companies and universities)

Economy	1995	2000	2005	2010
Indonesia	3.33	3.18	3.24	3.88
Malaysia	3.61	3.59	4.48	6.81
Singapore	5.87	6.03	6.24	6.89
Philippines	2.90	3.36	5.15	3.95
Thailand	4.12	3.05	4.17	4.48

Source: IMD WCY executive survey based on an index from 0 to 10, May 2011

Indicators measuring knowledge outputs

Table C.9: Real GDP Growth

Economy	1995	2000	2005	2010
Indonesia	8.20	5.30	5.70	5.80
Malaysia	9.80	8.90	5.30	7.20
Singapore	8.00	9.10	7.40	14.10
Philippines	4.70	6.00	5.00	7.30
Thailand	9.30	4.80	4.60	7.80

Source: WCY-2011(Percentage change, based on national currency in constant prices, JUN 2011)

Table C.10: Scientific and technical journal articles

Economy	1995	2000	2005	2010
Indonesia	129.5	181.6	205.2	200.75
Malaysia	365.8	459.6	614.6	880.0
Singapore	1141.4	2361	3611.2	3901.6
Philippines	144.7	184.6	177.9	197.0
Thailand	339.6	663.3	1248.6	1827.40

Source: WDI 2010

Table C.11: Computers per capita (Number of computers per 1000 people)

Economy	1995	2000	2005	2010
Indonesia	4.80	14.0	21.68	42.51
Malaysia	53.94	114.60	216.26	337.59
Singapore	207	439.80	601.02	827.48
Philippines	8	23.30	41.54	81.21
Thailand	18	48.40	66.12	122.61

Source: Computer Industry Almanac (Updated: JUN 2011), extracted WCY-2011

Table C.12: High-technology exports (% of manufactured exports)

Economy	**1995**	**2000**	**2005**	**2010**
Indonesia	7.22	16.15	16.30	13.20
Malaysia	46.10	59.53	54.59	48.11
Singapore	53.92	62.55	56.58	50.01
Philippines	36.80	72.58	70.72	65.65
Thailand	24.45	33.26	26.58	27.17

Source: WDI- 2010

Table C.13: Inflation (GDP deflator % GDP)

Economy	1995	2000	2005	2010
Indonesia	10	20	14	8
Malaysia	4	9	5	5
Singapore	3	4	2	-0.52
Philippines	8	6	6	4
Thailand	6	2	4	4

Source: WDI- 2010

Table C.14: Current Account balance % GDP

Economy	1995	2000	2005	2010
Indonesia	-3	5	0.09	0.8
Malaysia	-10	9	14	11
Singapore	18	11	21	24
Philippines	-3	-3	1.92	4
Thailand	-8	8	-4	4

Source: WDI- 2010

Table C.15: Annual growth of total factor productivity of ASEAN 5 countries, 1995-2010

Rank	**Economy**	**TFP**
1	Indonesia	0.0337
2	Philippines	1.0E-7
3	Malaysia	1.41E-14
4	Thailand	2.66E-18
5	Singapore	9.09E-22

APPENDIX - D

Table D.1 Different empirical approaches to RISs

Authors	Study countries	Inputs and outputs used in RIS model	Key results	Shortcomings
Matínez-Pellitero et al. (2008)	EU-15	EU-15 regional database	Factor analysis of the large set of variables	Concentrated on European region
Huggins & Izushi (2007)	Cluster region of Asia, Europe & North America	WCY data of competitiveness	Literature Review of regional clustering	No robust empirical analysis
Hsu, Y (2011)	33 European nations	European Innovation Scoreboard (EIS)	Benchmarking strategy	Application of DEA without correcting bias or extreme points
Erber, G (2010)	China	Policy analysis	Cross-section policy analysis of different Chinese region	No robust empirical analysis
Brökel, T & Brenner, T (2007)	Germany	German RIS database	Benchmarking German region and efficiency difference	Application of order-m method in single country cross-section analysis